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A GALVANOMETER FOR MEASURING RESISTANCE BY THE METHOD OF SUBSTITUTION.

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A galvanometer to be suitable for measuring resistance by the method of substitution must be sensitive to small *changes* in current strength. Its own resistance must be small in comparison with that which is to be measured; its coils close to the needle, so as to give a strong enough deflecting field; the controlling field weak; and the suspension of the needle delicate. Tangent galvanometers, and also the fairly sensitive galvanometers usually found in high school laboratories, are not suitable for this purpose. With the best of more than half a dozen such instruments which the writer found in a high school when he came to teach there, about five years ago, the resistance in series with it and a Daniell element had to be changed about 10 per cent in order to produce a barely perceptible change in the deflection; and when he recently questioned a number of physics teachers in the eastern states of the Union concerning their experience he failed to find a single one who felt sure that he could measure a few ohms by the substitution method closer than 20 or 30 per cent. And yet with such apparatus pupils are often expected to *discover* or to *prove* such things as the laws describing the variation of the resistance of a wire with its dimensions!

To improve matters the galvanometer illustrated in the accompanying figure was designed* The controling magnetic field of this is adjustable, enabling the sensitiveness to be adapted to the needs of the case in hand. It was found very easy to secure such sensitiveness that, when any resistance from 1 to 10 ohms was in

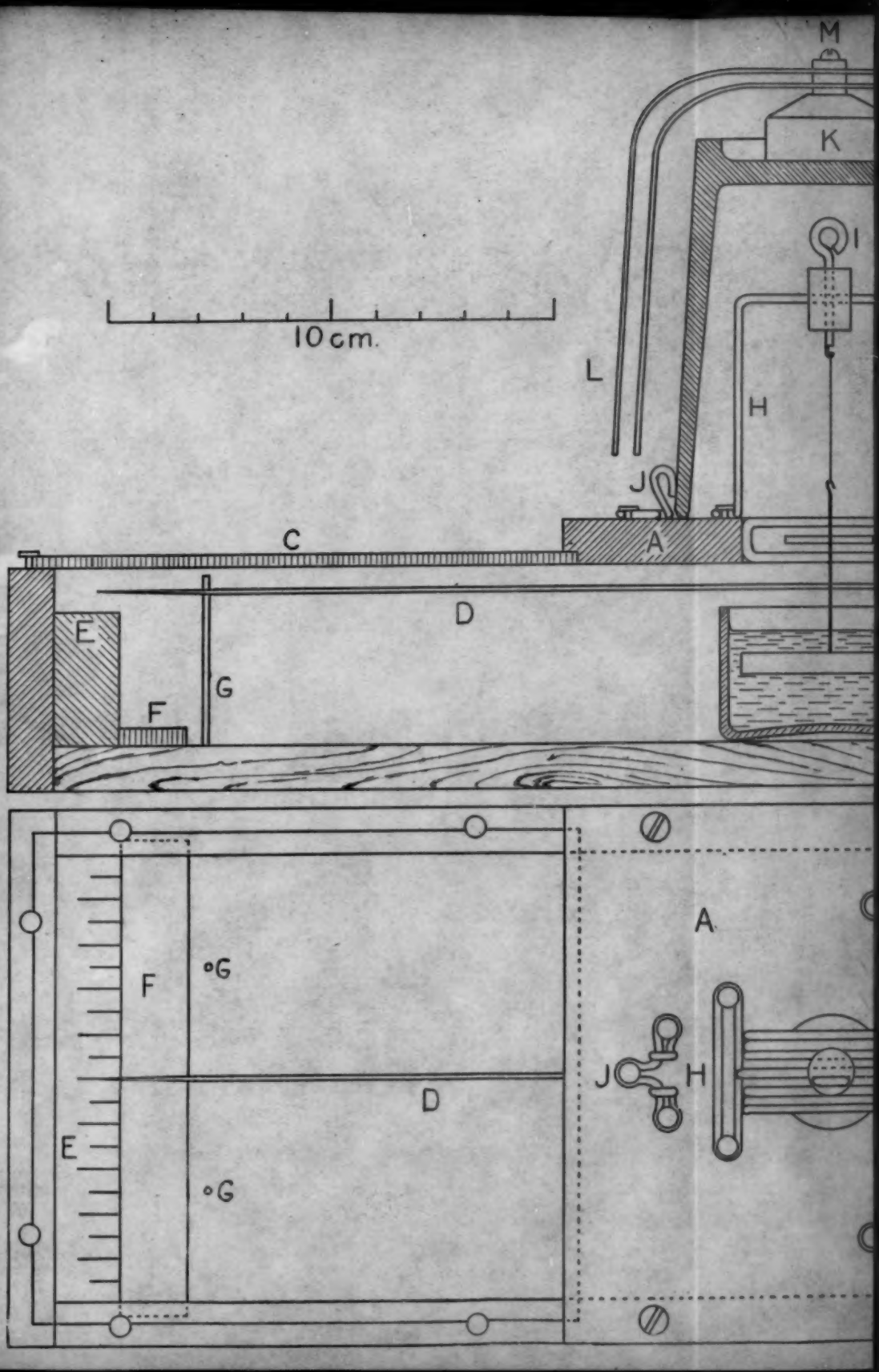
* In the plan the tumbler carrying the control magnets is removed to show the coils and the suspension.

series with the galvanometer and a Daniell cell, the deflection of a pointer 14 cm. long would change 0.1 mm. for a change in the resistance of from 0.1 per cent. to 1/40 per cent.; in fact, the falling off of the current furnished by the cell was perceptible in a few seconds. By using a longer pointer or a mirror, even smaller changes could readily be measured. This instrument is also easy to construct and cheap.

The coil, which is of rectangular cross section, is formed of six turns of ordinary insulated copper wire about 1 mm. in diameter, and is fastened with sealing-wax in a rectangular hole cut in the middle of the small board A, the ends terminating in the mercury cups B. To make room for the magnet suspension, half of the turns are slightly separated from the remainder. A is screwed as indicated across the top of a shallow rectangular box of wood, whose ends are covered by pieces of window glass C.

The magnet is a small bar of hard steel. Around this is wrapped and soldered a single turn of fine brass wire, which extends upward to form a hook for the attachment of the suspending fibers (3 or 4 of unspun silk), and downward to carry a small damper immersed in kerosene. The long, thin glass capillary D that forms the pointer is fastened with wax in a loop similar to that holding the magnet. One end of this is drawn out to a very fine point and dipped in India ink until this ascends two or three millimeters. The strong contrast between this sharp, black point and the white background of the scale E beneath (which may be a piece of measuring rod, or of co-ordinate paper divided into millimeters) enables tenths of divisions to be estimated with ease. Parallax is avoided by the use of the mirror F. Two brass pins G limit the motion of the pointer.

The brass wire frame H, bent out of one piece, is fastened with four copper tacks to the upper surface of A. Sliding with slight friction along the horizontal part of H is a cork, through a second hole of which slides the wire I, whose lower end terminates in a small hook for the attachment of the fibers supporting the magnet. This form of suspension permits motions in three directions at right angles to one another, as well as rotation about a vertical axis, so that the magnet can be centered and any desired torsion given to the fibers; and if the friction of the wires in the cork is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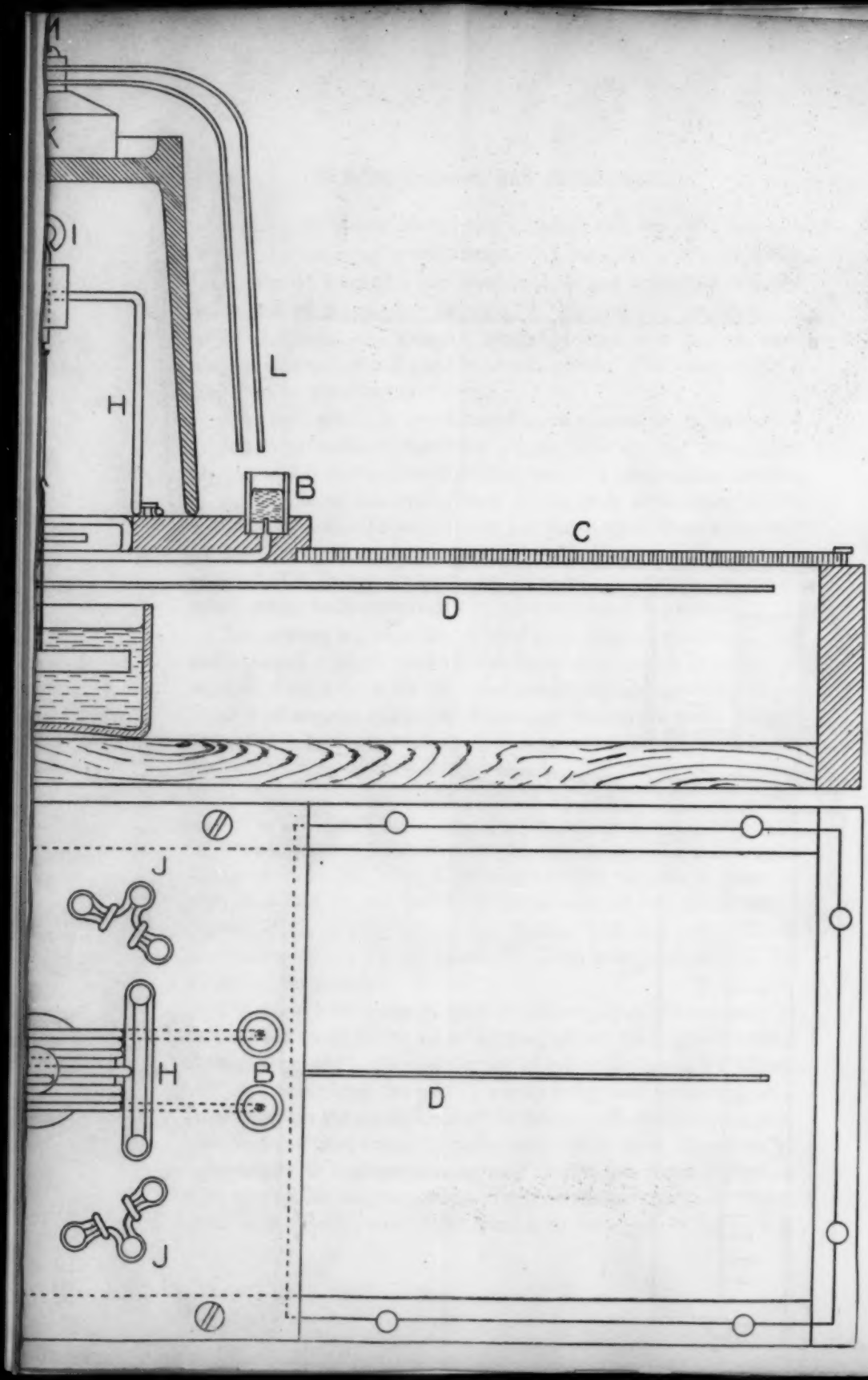
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eased with a little tallow, the adjustment can be made with great delicacy.

The whole suspended system is covered with an ordinary drinking tumbler, secured by the three wire springs J, so that it may be readily removed, and, when in position, may be rotated with slight friction about a vertical axis. On top is cemented a wooden block K to carry the control magnets L. These are made of old clock springs about 1 cm. wide, softened in the middle to permit punching or drilling the holes through whith the screw M passes for securing them to K. Brass or copper washers prevent their touching each other, and facilitate turning about M as an axis.

In assembling the parts of the galvanometer, the vessel for the kerosene must be filled and the glass pointer laid across its top before the board A is screwed in place. In order to balance the pointer so that it will be horizontal when freely swinging, the arm that does not come over the scale is made too long, and then gradually shortened by breaking off the end until it remains just a trifle heavier than the pointed arm. The final adjustment is made after it is mounted in the galvanometer by fusing the heavier end with a minute gas flame until the desired balance is obtained by the shortening due to the surface tension of the melted glass. If a mirror is substituted for the pointer, the horizontal dimensions may be reduced to those of A, and a window covered by a microscope slide must be placed in one side of the box.

When necessary to move the galvanometer, the suspended system is lowered until the pointer rests on the vessel containing the kerosene.

METHOD OF USE.

Connect the galvanometer in series with the unknown resistance and with a Daniell or other cell of constant E. M. F. and low resistance. The deflection will probably bring the pointer against one of the stops. Turn the control magnets until their like poles are somewhat near each other, so as to produce a strong field; and rotate the tumbler until the direction of the field is such that the pointer is brought to about the middle of the scale. Then gradually separate the like poles of the magnets until the field is just barely strong enough to hold the pointer in this position.

When the needle comes to rest, read the position to a tenth of a division. Then, without disturbing the galvanometer adjustment, replace the unknown resistance by a resistance box* divided to tenths of ohms, and find the deflections produced by each of two resistances differing by one tenth of an ohm, between which the unknown resistance lies. The hundredths of ohms can now be found by interpolation. If great sensitiveness is not desired, time may be saved by not weakening the control field so much.

ANOTHER ALGEBRAIC BALANCE.

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In the June number of School Science and Mathematics, F. C. Donecker describes an interesting balance designed to illustrate some of the fundamental operations on algebra.[1] The balance in question is quite fertile in posibilities. The use of the negative number, addition, subtraction, multiplaction and division of postive and negative numbers as well as transformations of linear equations are exhibited to the eye.

The writer has used similar devices in his classes in algebra. The apparatus described in this note is of the same general character as that described by Mr. Donecker. There are points of difference, however, which the writer thinks are of sufficient importance to warrant a description in this journal of the whole apparatus. The material required for its construction can readily be obtained from the physical or chemical laboratories of any well-equipped high school.

A hole large enough to admit a small bolt is bored through the center of an ordinary meter-stick, which is then made to swing freely about a fixed point, O, producing an ordinary balance. About twelve inches above the meter-stick is a fixed horizontal rod parallel to the meter-stick and slightly longer. This rod as well as the meter-stick may be clamped to ordinary iron standards, as shown in the figure. One end, A, of the meter-stick is connected with the fixed rod and also with the table by means of

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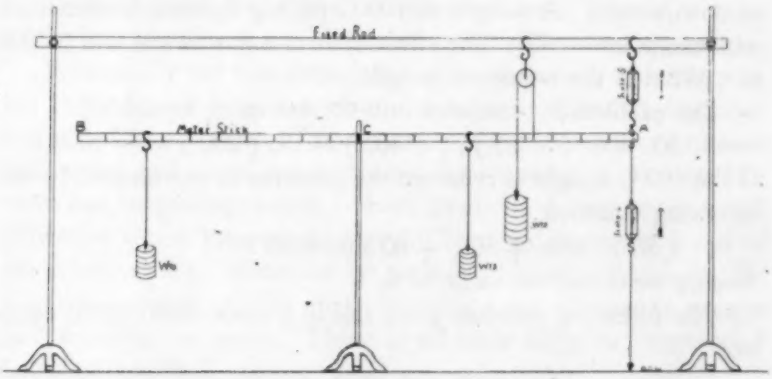
* A very convenient and easily constructed resistance box, which cannot be injured by such use, has been described by the writer in School Science and Mathematics, 32, p. 188, 1905.

1 "An Algebraic Balance," by F. C. Donecker, School Science and Mathematics, Vol. V, (1905), p. 411.

two spring balances as shown in the figure. These spring balances serve to measure any upward or downward pull which may be exerted at A.

The points on the meterstick between O and A are then labeled +.

Thus the point A is + 50, the point midway between A and O is + 25, while the point 20 centimeters from O, between O and B, is — 20, etc.



In the manner indicated in the figure suspend a 1 Kg. weight from the point 20, and note the reading of the scale. Place the weight at the point 40 and again note the reading of the scale, etc. By numerous experiments of this kind the following law is established: "If 'p' represents the downward pull at A, 'w' a given weight, and 'd' its distance from the point O, then w d = 50 p." (For the purpose of establishing this law the weights are suspended from points on the positive side only.)

It is most convenient to think of the force at A as tending to turn the meter-stick about the point O.

Weights can be made to pull upward as well as downward by passing the cord suspending the weights over a pulley as indicated in the figure. We agree to represent weights pulling upward by positive numbers and weights pulling downwards by negative numbers. Upward or downward pull at A as indicated by the scales S', S are likewise denoted respectively by positive or negative numbers indicating turning force in a positive or negative direction.

By experimentation we now establish the following laws of multiplication:

$$(-w) \cdot (+d) = (+w) \cdot (-d)$$
$$(-w) \cdot (-d) = (+w) \cdot (+d)$$

Problems of the following character are then proposed and solved:

Problem: An unknown weight is connected with the point + 30. (We do not know whether the weight is pulling upward or downward.) A weight of 400 G pulling upward is connected with the point — 35. The effect at A is a downward pull of 200 G. What is the unknown weight?

The problem is translated into the following equation:

$$30 \cdot w + (-35) \cdot (+400) = .50\,(200) = -10000$$

If the 400 G weight is removed the situation is represented by the following equation:

$$(30) \cdot w = +50\,(+80) = 4000$$

whence we obtain the value of w.

The following problem gives rise to a more complicated equation:

Problem: Two equal but unknown weights are connected with the meter-stick, one at the point + 50 and the other at the point —25. A +300 G weight is suspended at the point 20, a 500 G weight at the point — 40, a — 900 G weight at the point — 30. The total effect at A is a downward pull of 250 G. What is the unknown weight?

The ordinary algebraic method of solution of such problems may be represented step by step by remaining weight on the apparatus.

This apparatus admits of a considerable variety of problems. If all the weights are given the point of suspension of one weight may be found if the others are known. It also furnishes a convenient starting point for studying problems concerning the nature and extent of the determination of two unknown numbers by one equation.

Mr. Donecker's remarks on the need of concrete illustrations to prevent algebra from becoming mere symbol-juggling are very much to the point. The success or failure of any apparatus used for this purpose depends very much on the thoroughness with

which the class is made to study the physical principles involved in their operation. The apparatus just described is particularly simple in its construction. The writer's plan is to set it up as he needs it in the presence of the class during a regular recitation period, describing it as he goes along. A rough and ready apparatus of this kind is very often better than a dignified machine made to order. Too much machinery often gets into the way of the underlying principles.

In conclusion, the writer wishes to make a general remark on the introduction of negative numbers in elementary algebra.

Presumably our first experience with numbers is with integers, but these do not long serve our wants, and ordinarily fractions are added to our stock of numbers. As our experience becomes still wider and more exact the negative number is invented to meet our increasing wants. Now, fractions do not apply to all situations where integers do apply. Thus we cannot look out of the window $2\frac{1}{3}$ times, or go to bed $\frac{4}{5}$ times. Similarly, the negative number fails to apply in many cases where the integer and fractions do apply. There is no such thing as "negative 5 books on a table."

We learned to work with the positive integers and the fractions not by considering them abstractly, but by studying them in concrete cases to which they apply. How shall we study the negative number? Obviously in the same manner in which we studied the other numbers. It is very far beyond the attainments of the pupil studying elementary algebra to atempt to reason about them in the abstract. He must learn about these numbers in connection with many different cases where they are applied concretely. If this were our avowed program much of the difficulty with negative numbers would vanish. It is *only* after having studied the negative number concretely in many different cases that we are in a position to formulate general rules about them. We should be careful to specify that our information comes *only* from the concrete problems we have studied,—not from some learned and mysterious source, but from the plain, simple experience which we ourselves have had with them.

SOME POINTS IN THE HISTORY OF GREEK MATHEMATICS WHICH ARE USEFUL IN SECONDARY TEACHING.

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[CONTINUED FROM THE OCTOBER NUMBER.]

The first step into the algebraical domain was taken by Thymaridas. He went but little further than Nicomachus, but he enunciated an algebraical theorem. The chief importance of the proposition was that he used the phrase: "unknown quantity." It is not known whether he used a corresponding symbol, but he stated a theorem in algebraical form and used an algebraical expression. Mathematicians after his time appear to have continued to employ a process of algebraical reasoning expressed in words. No algebraist of marked originality appeared until 200 years later, when Diophantus, of Alexandria, took the final step by expressing equations in algebraical symbols. These equations were always treated analytically. The history of Greek arithmetic seems to have come to an end with Diophantus; for no original work by them is known to have been done afterwards.

The analytic form of reasoning followed by Nicomachus and his successors in the treatment of arithmetic was not original with him. It had been used in the treatment of geometry centuries before. It is said to have been invented by Plato. Hippocrates and other early Greek geometers used forms of analysis without knowing it, but Plato introduced it as a legitimate means and pointed out rules for its use. The result was that while he was no great mathematician himself, he was the maker of many great mathematicians. Among this number were Eudoxus, who invented practically the whole of the Fifth Book of Euclid, and Menaechmus, also a pupil of Eudoxus, who invented the geometry of conic sections.

These were followed by Euclid. While he did but little for arithmetic, he did much for geometry. His reputation rests mainly on his elements, a work which is, to a large extent, a compilation from the works of previous writers but which, is a systematic presentation of the leading elements of geometry,

and which has been the leading text in most European schools to within late years. He followed the example of Plato in limiting the mathematician in his constructions to the use of the rule and the compass,—a limitation which has been adhered to by later geometricians. An innovation, which is still followed in many schools is his plan for the orderly presentation of the steps in the demonstration of a proposition; namely, enunciation, statement, construction, proof and conclusion.

But Greek inquiry did not stop with mere activity of thought founded on observed facts, resulting in demonstrations and methods. It may have developed geometry and algebra thus; but when it came to mechanics and astronomy an inward effort of thought had to be exerted by which these facts were bound together under the form of laws and principles. The first to combine *facts* with *ideas* successfully was Archimedes. He was the first original thinker in this fashion and must be regarded as the author of the first sound knowledge of mechanics.

Archimedes established the proposition concerning the straight level by aid of a proof so simple that it is generally preferred by text-book writers to this day. This, together with many other proofs which he worked out, are the first mathematical proofs of propositions of mechanics. He laid not only the foundation of statics, but also that of hydrostatics. The story goes that his attention was first called to the subject of specific gravity by King Hiero's asking him to test his crown. The sequel to the story is that one day upon stepping into the bath the proper method of solving the problem occurred to him and he became so jubilant that he immediately ran home naked, shouting "Eureka.! Eureka!" At any rate, by weighing in water equal weights of gold and silver he ascertained the weight of the water displaced and so arrived at the specific gravity of metals. He may justly be credited with having worked out the two ideas that lie at the root of all mechanical science—that the whole pressure of a body downward is always the same, and the idea of a fluid as a body of which the parts move among each other by the slightest pressure and in which each part transfers any pressure exerted upon it to all other parts. Still, Archimedes' interest was

not with mechanics, but with mathematics. He did not care about the practical results of his work; it was the *proofs* he sought. Like Pythagoras and Plato, he held the opinion that to apply the intellect to the useful arts was degrading, yet he invented many of the most useful mechanical contrivances of his time. Of these, the most famous is the water-screw, which is still used.

Archimedes engaged also in astronomical observations. He was particularly interested in the question of the length of the year and made calculations which differed but slightly from those of later astronomers. He not only wrote a treatise on his observations, but actually made a globe and a mechanical contrivance exhibiting the movements of the sun, moon and five planets.

The motion of the stars and the spherical form of the earth were familiar to the Greek long before this, but his knowledge was based upon a single act or upon one great discovery. For instance, Anaximander, sixth century B. C., is said to have held the earth to be spherical. It is said, too, that he made some astronomical deductions by means of the gnomon, which he introduced into Greece. This consisted of a rod stuck upright in a horizontal piece of ground, and originally was used as a sun-dial. Some historians go so far as to state that he determined his meridian by marking the shadow cast by the style at sunrise and sunset on the same day, and taking the plane bisecting the angle so formed; and that he obtained the solstices by observing the time of year when the noon altitude of the sun was greatest and least; and that by taking half the sum of these altitudes he found the inclination of the equator to the horizon, thus determiing his latitude.

Pythagoras, who lived at the same time, applied his science of music to the study of the stars and tried to work out their distances from the earth by this means. He came to the conclusion that their distances formed a musical progression. The phrase "the harmony of the spheres" sprang from this notion. Aristotle remarks: "As to the figure of the earth, it must necessarily be spherical," but his reasoning is very faulty and is based upon abstract conceptions which he applied to the most general relations.

The first to make a systematic study of the planets was prob-

ably Aristarchus. He started with the hypothesis that the sun is the center of the universe and that the earth revolves around it. Then, through observing the phases of the moon, and the angular distance between the moon and sun when the former exhibits the half-moon phase, he measured the distance of the moon as compared with that of the sun. Although his results are valueless, he found the sun to be only eighteen times as far away as the moon, whereas it is nearly 400 times as far. Still he used a correct method and did much to create the spirit of applying mathematical calculations to astronomical observations. Later in the same century, Erastosthenes worked out the calendar, now known as the Julian, on the basis of astronomical calculations.

The most eminent of all Greek astronomers was Hipparchus. His methods of reasoning were purely *inductive*. He adopted the idea of epicycles, which had been suggested in the time of Plato, and applied calculation to the theory giving the conception a cleaness which certainly made it his own. He followed this with a numerical explanation of the movements of the sun and moon, supporting himself on the hypothesis of eccentrics. The main idea in his theory, and one which has not been disproved by succeeding discoveries, is the resolution of the apparent motions of the heavenly bodies into an assemblage of circular motions. The truth of this theory has been proved by the construction of tables of the motions of many of these bodies by which their positions are given at any time and which agree nearly with their positions as actually observed. The precession of the equinoxes is another of his discoveries and shows his careful and steady application in collecting observations and his clearness of comprehension of these ideas.

These investigations naturally led to trigonometry, and Hipparchus is credited with the invention of this subject.

We are indebted to Ptolemy, the last of the great Greek astronomers, for accurate accounts of the manner in which Hipparchus established his theories, his Almagest being founded largely on the works of Hipparchus. But Ptolemy's greatness lies in his taking two new steps in the application of Hipparchus' hypothesis. One of these was the application of the hypothesis

to explain the moon's evection and the other applied it in the planetary motions. His discovery of the moon's evection has clearly confirmed the idea that the motions of the heavenly bodies may be subject to inequalities and has overcome any disposition on the part of careful thinkers to guess as to the laws of nature from a few phenomena.

ARE ATOMS DIVISIBLE?

By Arthur A. Skeels.

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[continued from the October number.]

We will now try to show that the phenomena of light can be explained by the same structure of matter without recourse to anything contradictory to our experience in other branches of physics.

Fig. 11

Let Figure 11 represent a molecule of oxygen, consisting of a pair of atoms. To attempt to explain the phenomena of the spectra on the hypothesis that these atoms are indivisable, leads one into hopeless difficulties, but if we consider the atoms to be composed of smaller subatoms and that light is produced by the vibration of these subatoms, the matter becomes comparatively easy. Each subatom by its vibrations sends out light of a particular wave length, depending upon its mass and the attractive influences to which it is subjected. The oxygen atom, if it sends out at least sixty different wave lengths of light, might well be expected to have at least sixty different subatoms.

In reality, however, this number is doubtless much greater, for not only would we expect two or more subatoms to give practically the same wave length under the proper conditions, but also that only those subatoms at or near the surface of the atom would be able to emit an appreciable amount of light.

Anything which changes the attractive influences upon the subatom will change its time of vibration, and thus the wave length of light it produces; hence, an element gives a constant spectrum only under constant conditions. An element in the gaseous form, rarefied enough so the molecules are practically separate and distinct, will gave at a constant temperature prac-

tically a constant spectrum, because the subatoms are under practically constant attractive influences. At a higher temperature the atoms themselves expand by the increase in the amplitude of vibration of the subatoms, the attractive influences change, the time of vibration and hence the spectrum changes. If the element becomes denser, and especially in the liquid or solid form, these same subatoms are acted upon by the varying attractive forces of the neighboring vibrating atoms, now packed closely together, the times of vibration of the subatoms not only are changed, but are changed in a very irregular manner. Even the same subatom may give successively many different wave lengths, as its time of vibration continually suffers change by the movements of the adjacent atoms. This gives all kinds of wave lengths, that is a continuous spectrum.

When an element unites with others, the new combination of atoms changes the attractive influences on the subatoms, and hence their time of vibration, and thus the spectrum. An element combined with others no longer gives the same spectrum as when alone.

In the same way that the collisions of ordinary bodies set the molecules vibrating, so do the collisions of the atoms in heated bodies set the subatoms vibrating, and when this vibration reaches a certain intensity or amplitude, appreciable light is emitted; that is, bodies heated to a certain point give out light. In the same way that the application of a given amount of mechanical energy will cause some substances to radiate more heat than others, so will the application of a given amount of heat energy cause some substances to radiate more light than others, or, in other words, some substances are more efficient as light producers than others.

The internal arrangement of the subatoms within the atom has much to do with the character of the light emitted. A striking example of this is shown in the case of phosphorus. The chemical behavior of this element indicates that the subatoms of ordinary phosphorus are loosely put together, but when under certain conditions they draw more closely together, they form the denser atoms of red phosphorus. In the former case the subatoms are extraordinarily free to vibrate, and so give out light with a very low expenditure of heat energy, while in the latter

case this freedom is restricted, and more energy is required to cause it to produce light.

All subatoms of all substances at all temperatures are continually in a state of vibration, but they must have a certain rapidity and a certain amplitude to emit waves appreciable to the eye, similarly to the way that vibrating bodies in the air must have a certain rapidity and a certain amplitude in order to send out waves appreciable to the ear. Even at ordinary temperatures there is an enormous amount of energy stored up in bodies in the form of molecular and atomic vibrations (heat). Also in addition to this there is an enormous amount of energy stored within the atoms by reason of the vibration of the subatoms.

The same laws of sympathetic vibrations that are well known in sound also hold true for light. Subatoms will absorb the same kind of vibration they emit. But if subatoms are thus set in vibration it means that light under the proper conditions, causes atoms to expand and by changing the distance apart of the centers of mass will thus change the attraction between atoms. This affects the stability of molecules, and thus light in certain cases affects chemical changes.

Subatoms set in vibration by action of light will, on account of inertia, continue to vibrate for a time after the disturbing light ceases. Thus the subatoms so affected continue for a short time to give out a feeble light.

Those particular subatoms which naturally have the same time of vibration as the incident light, will be set in more intense vibration than any others, and give out the light called phosphorescence. But also those subatoms which naturally have a time of vibration bearing a simple ratio to that of the time of vibration of the incident light, will likewise be set in vibration, and give out light of longer or shorter wave length than the exciting rays. Thus we have calorescence and fluorescence. Analogous phenomena are found in sound.

If white light strike a substance it often happens that a certain portion of the incident vibrations correspond to those of the subatoms, these portions of the light are more or less absorbed, the remaining light reflected is no longer white. The color of a body in white light depends upon the vibration frequency of its subatoms. Gold offers a striking illustration of this. The sub-

atoms of this substance, under ordinary conditions, have a time of vibration coincident with that of green light. If white light strike gold most of the green rays are absorbed in setting the subatoms in vibration, while most of the other rays are reflected. This vibration of the subatoms is communicated from one to another, and extends a certain small distance into the gold.

This distance is greater than the thickness of the thinnest goldleaf, so when white light strikes the goldleaf, all of the subatoms are set vibrating, and give out green light on both sides, but only on the reverse side, where it is unmixed with the reflected light, does it become appreciable. This same explanation applies to all substances whose transmitted light is of a different color than the reflected light. The abnormal spectra often given by this kind of substances, is due to the conduction of these vibrations from one subatom to another in the direction of least resistance, which is independent of the direction of the rays in ordinary refraction.

Since this absorption depends entirely upon the subatoms, any condition which affects the vibration frequency of the subatoms will affect the color of the body. A change of temperature, chemical combination or even a solution, may, by changing the attractive influences, bring about a change in vibration frequency and color. Sometimes a change of color is due to an allotropic change in an element. For example, when the subatoms of ordinary phosphorus draw more closely together to form the denser atom of red phosphorus, the vibration frequency of the subatoms increases on account of the greater attractive forces due to their being closer together, a higher frequency light is thus absorbed and a lower frequency light is reflected.

Sometimes a subatom, as in Figure 12, is acted on by attractions which differ in different directions, so the time of vibration in direction *"ab"* is different from that in the direction *"cd."* That is, if white light strikes that kind of subatom the kind of rays absorbed will depend upon the direction of the incident rays. That is, the colors shown by the body change with the change in the angle of incidence, as is shown by iridescence, opalescence, etc.

Fig. 12.

The explanation usually advanced, that this change of color

is an interference phenomenon, due to the laminae or striae of the substance, is applicable only in special cases. In general these laminae or striae, if they exist, are molecular, and altogether too small to produce interference.

When the temperature of a body is gradually raised, red light is at first given off, then orange, yellow, etc., to violet. Thus it has been very generally taken for granted that the rapidity of vibration increases with the temperature. But we are not justified in drawing this conclusion. In sound an increase of energy does not raise the pitch of a vibrating body, but increases its amplitude; similarly an increase of heat energy will not increase the rapidity of the vibrating subatoms, but rather their amplitude; that is, the intensity of the light emitted. When the temperature of a body is raised, those subatoms which are under the least attractive influence will be the most easily set in vibration, and at the same time vibrate the slowest; that is, give the longest waves. As the heat energy increases, other subatoms under greater attractive influences and having a more rapid frequency are brought successively into sufficient vibration to emit appreciable light. Instead of a higher temperature increasing the vibration frequency of given subatoms, it will, in general, by expanding the atom, so decrease the attractive forces on the subatoms to decrease their frequency. An example of this is shown by the sulphide of strontium.

At —20° its phosphorescence is a dark violet, at 40° a bright blue, at 70° a bluish green, at 100° a reddish yellow. That is, an increase of temperature actually lessens the vibration frequency of the subatoms. As ordinary bodies in vibrating send out waves in the air, a substance consisting of molecules of similar magnitude to the molecules of the vibrating bodies, so do the subatoms in vibrating send out waves in the ether, a substance made up of particles of similar magnitude to the particles of the vibrating subatoms; that is, the ether is a sub-subgas. Analogy would further demand that like sound waves, light waves should be longitudinal waves of condensation and rarefaction. In fact, such waves are readily conceived, and are the kind we would expect bodies vibrating within a medium to produce. But we are taught that light waves are not only transverse, but also vibrate

in every plane passing through the line of direction of the light ray.

Such a set of waves caused by vibrating bodies within a medium is not only contradictory to all known experience, but a little study will also show that it is utterly inconceivable. But it will naturally be asked, how can we explain polarization and rarefaction? That is, what we will now try to do.

Let Figure 13 represent one of the fundamental particles of ether made up of a pair of sub-subatoms, analogous to the way that oxygen, hydrogen, etc., are made up of particles consisting of a pair of atoms. These ether particles have in general three motions; translation in straight or curved paths, vibration amongst each other and rotation. In the same way that the amplitude of the vibrating air molecules in sound waves is very large compared with the distance apart of those molecules, so is the amplitude of the vibrating ether particles in light waves very large compared with the distance apart of those molecules, so is the amplitude of the vibrating ether particles in light waves very large compared with the distance apart of those particles. Furthermore, under ordinary conditions, the ether particles rotate in planes which make every possible angle with each other, but under certain conditions or influences a certain portion of the ether will have the particles all or nearly all, rotating in planes parallel to each other. Light in this ether is polarized.

Fig. 13.

Let us take up a few special cases. Let "*ab*," Figure 14, be a highly magnified layer of some substance capable of polarizing light by transmission. Suppose also that the light wave, one of condensation and rarefaction, moves in the direction of the arrow with the ether particles vibrating through the amplitude "*cd*." The material of "*ab*" is of such a structure that those ether particles rotating in certain parallel planes are able to pass through more easily than those rotating in other planes. As the crest of the first wave passes through "*ab*" most of the ether particles which get through, are rotating in planes parallel or nearly parallel to each other, but these ether particles go but a short distance before they collide with other ether particles

Fig. 5

ahead of them, which are rotating in all planes. The effect of the collision between the polarized and the unpolarized particles is to knock a part of the latter around into the same plane as the former, that is, to polarize them also, and at the same time to destroy the polarization of some of the former. But as the waves follow each other in rapid succession, the ether particles continue to vibrate to and fro between *"c"* and *"d,"* so no matter how many ether particles after passing through *"ab"* may be knocked out of their planes of polarization, they are put back into it again by a repeated passage through *"ab,"* and these in turn keep hammering away at the next layer below, until they also are all knocked into the same or parallel planes. These latter hammer away at their neighbors ahead until they likewise are brought into the same plane, and so on indefinitely.

That is, the light below *"ab"* is a series of vibrations in ether, whose particles are all rotating in parallel planes. This light is polarized. By inertia these particles continue to rotate in the same planes until outside disturbing influences destroy this uniformity. Owing to the great velocity of light this is often not accomplished within the limits of our observation. Of course, it can readily be seen that another layer of the same substance placed below *"ab,"* in the same sense, will allow the polarized light to pass, but will stop it if crossed. In practice the polarizing effect is less perfect than the case just cited, but at any rate acts on the same principle.

In Iceland spar the structure of the material is such that only those light waves consisting of ether particles rotating parallel to a certain plane can pass freely through the ether within. This light is thus polarized, and forms the ordinary rays. The rest of the light is thus left polarized in a plane perpendicular to the ordinary rays, and is transmitted through the material of the spar with a retardation, which, in general, is different from that of the ordinary rays, and also varies somewhat according to the lines of material along which it is transmitted. That is, not only are two sets of waves separated, but also the relative position of the extraordinary rays depend somewhat upon the way the crystal is turned.

Double refracting substances may be added to those already mentioned as giving evidence that light may be transmitted

through the material of some bodies as well as through the ether within those bodies.

A subject of this kind has no end. No matter where we stop, it is bound to be left unfinished.

ON SCIENCE TEACHING. II.

By C. R. Mann.

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A great deal is being said and written nowadays about correlating subjects in the school curriculum. And by this is generally meant the teaching in one department of subject matter usually classed as belonging to another department. Thus we are said to correlate mathematics and physics by teaching mathematical principles in connection with physical experiments; or, as it is sometimes stated, by rendering mathematics concrete by basing its theorems on physical phenomena.

Useful as such correlation is, it must be clear to the thoughtful teacher that it lacks an element of reality—that it is at best but an external makeshift, guided by no fundamental principle, and based on nothing that is vital to both subjects. Yet it indicates progress, and the presence of a vague sense that there must be some grounds or principles common to the different branches of instruction. Let us see if such a relating idea cannot be found; for evidently there can be no real correlation among subjects unless it is based on something that they all possess—some unifying, central, basic principle.

In order not to make the discussion too broad, this paper will be devoted to a discussion of the sciences only, leaving the more general question for later consideration. What, then, we may ask, is the unifying idea among the sciences? What is it that they all have in common, and without which they would not be sciences?

The answer is not hard to find. It may, perhaps, be made most forceful by considering first why there was no science during the Middle Ages, and what was needed to bring science into being. No one to whom this question is put will hesitate an instant to reply that science began to blossom and bear fruit when men began to use the scientific method of investigation.

Therefore, is it not true, that it is this scientific method of investigation which is above all things the center and soul of science? Is it not the one thing which the sciences all have in common, and without which they would not be science?

If this scientific method of thought is the chief characteristic of science, it becomes of interest to try to define it more clearly—to attempt to find out whether all the sciences are equally good exponents of it, and whether they all use it in the same way. A complete discussion of this question is beyond the scope of a brief paper like this, even if it could be given at all. There are, however, some interesting facts which appear from even a brief investigation.

In the first place, it is noteworthy that the various sciences are not equally old. Thus geometry is the oldest; then comes formal astronomy. These two were cultivated by the Ancient Egyptians and Greeks. In the sixteenth century chemistry and physics became sciences. These were followed in the eighteenth by the biological sciences, and, finally, in the nineteenth century, came sociology, claiming place with the rest.

Now, if, as has often been rightly said, the function of science instruction is to train in the scientific method of thought, would the same conception of that method be obtained from a study of each of these sciences? Yet if that method can be staked off into the four steps of observation, induction, deduction and verification, why do we fail to recognize the mental processes in geometry and in sociology as the same? Is geometry wholly deductive, and sociology wholly inductive?

Whatever may have been the method employed in obtaining the axioms of geometry, its present methods seem to be largely deductive, i. e., it is an exemplification of the latter stages of the scientific method. It is also the oldest of the sciences. Sociology, on the other hand, has not reached any axioms, nor yet any working hypotheses as well developed as is that of the conservation of energy in physics. In other words, it is in the earlier stages of the scientific method. It is also the youngest of the sciences. Does not sociology use deduction and verification? Certainly; but, in a general way, its processes illustrate the earlier stages of the method under consideration.

The biological sciences, though vastly more advanced than

sociology, may be considered to be still engaged in the process of building their general principles, while physics and chemistry have reached some of theirs, and are working both inductively and deductively for the attainment of others. From this point of view, then, we might consider that, in a general sort of a way, the older the science, the more it becomes an exemplification of the later stages of the scientific method, while the newer sciences are mainly involved in the earlier stages.

If this point of view be taken, it follows that if we would master this method completely in all its intricacies, we should have to study in detail the processes employed in all the sciences. This method is, then, not so simple an affair as it may at first sight appear to be. And, in fact, the more we try to analyze the two processes which we so glibly call induction and deduction, and to distinguish in detail between them, the more inextricably entangled we find them to be. Follow any argument into detail, and see if you can determine definitely which part of it is wholly inductive, and which deductive—see if you can find portions that are deductive only. In general this is easy to do, just as it is apparent on the surface that the methods of geometry differ in general from those of sociology.

In short, the scientific method, if followed too much into detail, is found to be very complex. It has been rightly called the modern logic, and it is as much more complicated and involved than the logic of Aristotle as the modern life is more complicated and involved than that of the Greeks. Yet there are several very definite things about the scientific method which it is of great value to science teaching to understand, if we are to teach the sciences in a correlated way. These things must be sought in the general scientific attitude, rather than in the detailed processes employed in any particular case; these latter are too complicated to be able to guide us in general.

The first of these general characteristics of the scientific attitude is the habit of basing all conclusions on observed facts, not on hearsay, not on authority. Until a child has learned to keep apart in his mind the facts which he has himself observed and those which he has read of or heard of from others, he has not started fairly toward the attainment of the scientific attitude of mind. If we could all learn not to pass along to others as facts

things learned from authority only, the world would be a far different places to live in. If we could all learn not to form too fixed conclusions from things learned from hearsay only, what an enormous saving of mental effort would result. This is the first great thing which it is the mission of science, as teacher of the young, to impress on mankind. Train them so that they distinguish carefully between the things observed by themselves, and those facts learned from reading or from conversation with others.

It does not follow from this that a student should find out everything for himself; not yet that he should make all the quantitative experiments himself in the laboratory. He usually has a large amount of qualitative personal experience with the subject matter of science, and can generally obtain a large store of personally observed facts in the routine of his daily life, if only he will keep his eyes open. It does, however, imply teaching him to regard as most real the conclusions based on his own observations.

The other important element of the scientific attitude is the maintenance of an unbiased and impartial mind. This is by far the most difficult attainment; for we have been so trained for centuries to accept things as dogma on authority, and to learn them from books, that it is difficult to develop that freedom of the personal judgment which is so essential, not only in scientific work, but also in all else that we do. Progress is effected through the action of free thinking individuals who form their conclusions by a personal judgment acting in freedom. Anyone who has developed in him such a really free attitude, must also respect the same thing in others. He must be tolerant, as well as individual. Such a free, personal judgment is also the center of self-activity, for who that is not free can be original?

These two things thus seem to be the essentials of the scientific attitude; and, therefore, for correlation, they should be made the chief aims of science instruction. It is after all immaterial whether a boy or a girl knows the lens formula, or can recite from memory Newton's laws of motion, if he has these two mental traits well developed. But it is an interesting fact that children trained to observe carefully and to reason

from those observations clearly and in freedom remember both the facts and the conclusions better than if they are taught the conclusions as a matter of authority. Though it may seem paradoxical, it is yet true, that if we make it our aim to teach the facts and principles of science, we fail; but if we have as our sole purpose the development in the children of this scientific attitude, they not only acquire that most valuable possession, but also learn the principles better. Moreover, by the adoption of this aim, the sciences become truly correlated. They then come to stand in the curriculum for a certain definite kind of attainment: not for a smattering familiarity with a few facts and theories of physics, of chemistry, of biology,—all the work of other men's hands than theirs,—but for acquired power, free judgment, greater individuality.

One thing more. The scientific method is but a part of a general process of human action. For everything we do may be analyzed into three distinct steps, or phases. In the first place, and most essential, we form a purpose. Can you conceive of an action without some purpose? Are not the great men, the interesting men, those of mighty purpose? In the second place, we find means for the accomplishment of this purpose. And finally, through the means we carry the purpose into action and produce a result.

Now, the scientific method by itself is but the means, and leads to the result. It has no purpose. It is a mere tool. Yet if it is to be a real part of a human action, it must be used in the service of a strong purpose. In the case of the scientist, the purpose is immanent and powerful, for he is fired with the desire to unravel the mysteries of the universe. But how about a student when confronted with one of our ready-made systems as described in a science text? Suppose he knows nothing of science, what is there to awaken in him a purpose to study the subject? It is often said that we must rouse interest; but is not interest but the manifestation of a purpose? Should we not rather strive to stir up in the youngster a purpose?

This cannot be done in the case of a young student by telling him of the value he will receive from the work in some future age. It may possibly be done through his curiosity. It is at best a subtle thing, this purpose; yet fundamental. For certain

it is, that if he has no spontaneous purpose, he has no interest, and no self-activity, and does not develop free judgment,—"and the fire won't burn the stick, and the stick won't beat the dog, and the dog won't bite the pig, and the pig won't jump over the stile, and I won't get home tonight."

Have not the science teachers a great field of investigation here? Who can tell how purposes are formed in a child? Who can learn to govern or guide them? Yet are they not the reality on which our success or failure in the last analysis depend?

TROPICAL FRUITS.

BY MEL T. COOK.

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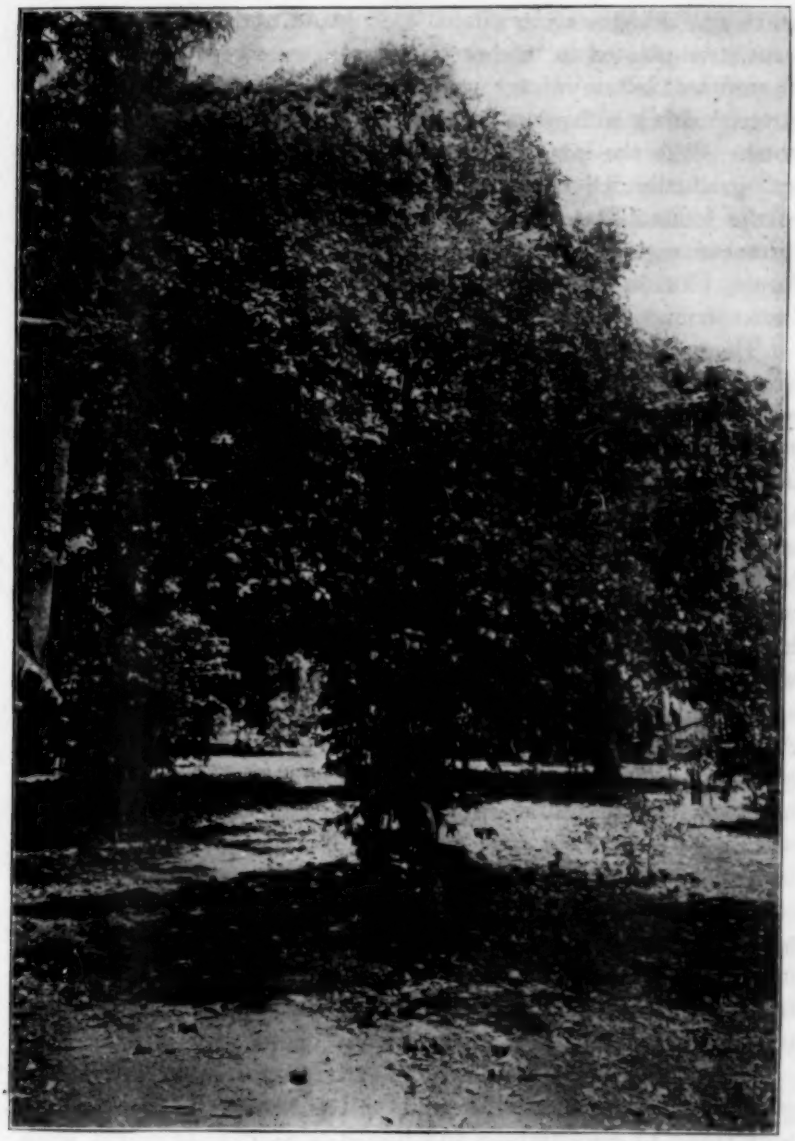
III. Orange.

Probably no tropical fruit is so well known and so universally used throughout the civilized world as the orange. In fact it is one of the oldest of cultivated fruits and one of the first to extend its range from its original home. Probably for this reason has its nativity been in such great doubt. It is now generally believed to be of Indo-Chinese origin, and it has undoubtedly been cultivated in India, China and Japan from very remote time. Wild oranges are now said to be very abundant in northern India. It is supposed to have been carried from Hindustan to southwestern Africa by the Arabs probably before the ninth century, and by that same race it was carried on the tide of the Mohammedan conquest and distributed throughout northern Africa and into Spain. But it was destined to come into Europe from another source, and about the twelfth century was introduced into Italy by the returning Crusaders. There its cultivation gradually increased until about the sixteenth century, when it became very common.

From the Mediterranean region it spread throughout the world wherever the conditions were favorable for its growth and is now cultivated in practically all warm, temperate and tropical countries. It is said that the first English settlers in Florida found many trees growing wild. Undoubtedly the seed had been introduced by the early Spanish explorers and settlers, and then carried from place to place by the Indians.



AN OLD CUBAN ORANGE TREE IN FULL FRUIT, ALLOWED TO GROW WITHOUT CARE OR CULTIVATION.

Before the days of rapid transportation and until about fifty years ago oranges were raised in England under glass. These trees were planted in tubs or boxes, and were kept out of doors in summer, but in winter were moved into houses which were covered either with glass or with slate and had numerous windows. With the improvement of transportation these "orangeries" gradually fell into disuse. Until recently the greater part of the United States' supply of oranges came from the Mediterranean region, but this was gradually superseded by the California, Florida, and to some extent, by the Mexican and West Indies fruit.

There are three orange growing districts in the United States: California, Central and Southern Florida and the Delta of the Mississippi river in Louisiana. Oranges were grown to some extent for family use in Florida before the Civil war, but the industry did not attract attention as being of much importance until after the war, when it gradually increased until it became of great value. The industry has been greatly checked by the freezes of 1894-5 and 1900-01. Previous to 1880, the winters of Florida were almost frostless, but since then frosts have been more or less common. The first injury due to frost was in 1886, and in 1894-5 there were freezes in December and again in February, which caused a loss of about $100,000,000. A second severe freeze in 1900-01 has had a very discouraging effect upon the industry. This very great change in temperature has probably been due primarily to the destruction of the natural forests of the state and is another demonstration of the fact that commerce frequently trades as the small boy, from one pocket to the other until the loss in exchange between the two eventually leaves him with nothing. Had the forestry business been under proper government supervision, Florida might today have two great industries, oranges and lumber, instead of two fragments.

The oranges of California and Arizona are subject to much greater cold than Florida, but suffer less because of the greater uniformity of temperature and humidity.

Both the trees and the fruit of the orange vary greatly in character and that is one of the factors that has made it such a valuable fruit since the tendency to vary gives rise to great

numbers of valuable varieties. The fruit normally contains ten compartments, but this number has been greatly increased by cultivation. In some cases a secondary axis, known as the "navel," has been formed, giving rise to the celebrated Washington Navel, which is one of the most popular California oranges. This orange, like most other valuable varieties, was a mere chance seedling which originated in Brazil and was introduced into the United States in 1870 by Wm. Saunders, of the United States Department of Agriculture, and distributed under the name of the Bahia.

In Cuba, which is one of the first American countries into which oranges were introduced, wild seedlings are very abundant and the number of valuable varieties unknown. When the oranges first ripen they are not necessarily yellow and, since many of them unless carefully cared for, will be dark colored owing to the attack of insects and fungi, they present a very uninviting appearance, but are none the less delicious. The market demands a yellow orange and a red apple, and many of the beautiful yellow but extremely sour oranges of our northern markets have been colored artificially to please the eye of the consumer.

The orange belongs to the family *Rutaceae* and the genus *Citrus*. It is an aromatic, glandular shrub or small tree, usually thorny; the leaves are alternate, flowers hermaphrodite, calyx cupulate 3-5 toothed; petals 4-8 linear-oblong, thick, glandular, imbricated in the bud; stamens 20-60, but occasionally only 5.

The common orange is *Citrus vulgari*, Risso, var. *sinensis* Engler, which is probably most extensively cultivated.

C. limon, Linn, is the lemon and the var. *ocida* Hook, is the lime of commerce.

C. pomelanus, Hort. is the pomelo, shaddock and other very large citrus fruits which are so rapidly coming into popularity and which are sold under the common name of grape fruit.

C. Japonica, Thunb. is the Japanese pumquat or cherry orange, which has proved so popular as a novelty fruit.

Bergamia, Wright & Arn, is a variety of *C. vulgaris* from which the bergamot oil of commerce is derived.

For some years the United States Department of Agricul-

ture has been conducting a series of experiments with both seedlings and hybrids for the purpose of developing a hardy variety suitable to the climatic conditions of the southern parts of the United States. An account of this work is given in the U. S. Department of Agriculture Year Book for 1904.

Oranges are frequently raised in our northern states for ornamental purposes, but in many cases the results are unsatisfactory because of the belief of many people that tropical plants grow continuously the year round. After fruiting, these ornamental trees should be allowed two months rest at a temperature of 40 to 50 degrees, and with a limited amount of water.

Oranges, like all plants that have been introduced from foreign countries, are subject to many insect pests, fungus and bacterial diseases. An introduced plant is always subject to a greater or less extent to new diseases which are common to other more resistant plants of its new home and these diseases are carried with the plant in its introduction from country to country. So the orange grower must always contend with many difficulties if he is to grow a successful crop of fruit. However, thanks to the work of our Department of Agriculture and to the many State Experiment Stations, these diseases are being studied and methods devised by which they can, in a great measure, be controlled.

WHERE SHALL THE COURSE IN ZOOLOGY BEGIN?

By Worrallo Whitney.

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Probably a large majority of the teachers of Zoology begin the course with the lowest forms and take up the various groups in the order of development, proceeding from the lowest to the highest in as nearly regular sequence as practicable. But a very considerable number of teachers prefer to begin with a higher type, such as the grasshopper or the crayfish. Recent textbooks, like Colton's and Davenport's, adopt the latter plan, while Jordan, Kellogg and Heath's "Animal Studies," and Kellogg's Elementary Zoology, begin with the lower types. Peabody, in his contribution to the "Teaching of Zoology," makes a strong argument for commencing with the crayfish. I wish

to examine the arguments for the irregular order of study and show why it is not a good plan for the average zoology teacher to adopt, or, to put it more truthfully, why I believe it is not the best course for any teacher to adopt.

In the case of those who like to start with the crayfish the principal incentives are in the size of the animal, its interesting traits and convenience for use, and the important problems that may be worked out by its study. Now, of course, all these good points are just as good when the crayfish is reached in the regular order, and so far as the study of the animal is concerned there is nothing gained or lost by the difference in time in taking up the study. The question, then, really is as to whether the crayfish is a good type for *beginning* the work in zoology from the standpoint of results to the pupil.

What are the objections to using the crayfish in this way? Every enthusiastic teacher wishes his pupils to develop a liking for the study and to take pleasure in it. If one goes beyond a superficial study of the crayfish and tries to develop the zoological principles that may be brought out, such as homology, differentiation, specialization, etc., a thorough laboratory study must be made as a basis for developing these principles. With beginners this would require several weeks time. For the average teacher there would be serious danger that disgust rather than enthusiasm would be awakened by such a prolonged study, when we take into account that most of the work must be done with dead material which, in the case of the crayfish, cannot be made very attractive, to say the least. Apropos to this, I remember meeting some pupils of a course in zoology, which began with a laboratory study of the soft shell crab. All they seemed to have retained of that course was the memory of those alcoholic specimens of crabs over which they had held their noses daily for some weeks. While this was an exaggerated case undoubtedly, it points out a real difficulty. The success of the course depends upon the good will of the pupils for the work and a failure to secure this good will means the failure of the teaching. It would be simply marking time, but not teaching.

To add to the danger from this point, the difficulty of the study of the crayfish must be taken into account. The crayfish is a highly specialized animal and there are a great many parts

with a very formidable array of names to be memorized. Laboratory work to be valuable must be recorded in accurate sketches, and those required for the crayfish are among the most difficult in the entire course. Altogether it would seem that only the most expert teachers could hope to carry beginning classes safely through the crayfish studies without loss of interest through discouraging difficulties and unpleasant material.

But, to my mind, these difficulties just mentioned are of minor importance compared with the pedagogical error of such a course. All the zoological principles which the teacher of zoology strives to have his pupils gain an understanding of from the study of the crayfish are, after all, but names for certain external indications of the efforts of the crayfish race to adjust itself to its environment. The crayfish has its problem of life and has been adapted in structure to solving this problem. To appreciate this underlying principle which explains and gives meaning to all else, the pupil needs a back ground of the study of several animals, but especially of the lower animals where the response of the animal is more obvious, such as the case of the Annelid worms with a comparison of Nereis and the Earthworm. The pupil who is meeting the crayfish as his first study can have no comprehension of the effect of habitat upon the animal, and the zoological principles he gathers from the crayfish have no meaning or explanation to him—they would be simply "hung up in the air" until the requisite back ground could be secured. Pedigogically, then, I do not see how the study of the crayfish for beginners can be defended.

Those who begin with the grasshopper may be divided into two groups, viz., those who are led to it for the same reasons that make others choose the crayfish, and those who begin with the grasshoppers for the sake of studying insects at a favorable time of year. The objections made to the study of the crayfish for beginners apply equally well to the grasshopper study. But, I do sympathize with those teachers who wish to study insects while they are alive and to be found in every vacant lot. However, I have a plan explained further on which seems to meet this need felt by all teachers who use the regular order of studies as well as those who begin their course with the grasshopper.

Let us consider now the objections often made to beginning the course with the Protozoa. The following seem to be the principal objections: 1. The pupil must at the outset learn the use of a complicated instrument. 2. The pupil's view of the animal is distorted because he sees them greatly magnified. 3. There are serious difficulties of manipulation both with the microscope and with the material. 4. A fine opportunity for field work is lost while the pupil is at work on these lower forms. I shall take up these objections in order.

So far as my experience goes, pupils are always eager to learn all about the microscope, what it can do and how it does its work. If care is used there is little difficulty in teaching the use of the microscope and, indeed, it must be done sooner or later. I have found that the opening days of school while the classes are forming are particularly favorable for this work. As to the second and third objections it all depends upon how the Protozoan studies are planned. I would not think of trying to start off with an Amoeba study. If the Paramoecium is used for the main Protozoan study there will be little difficulty. They can be cultivated in the laboratory by the million with almost absolute certainty of having them ready at just the right time. They are large enough to be seen with the unaided eye and a correct idea of their real size obtained. Nearly all the observations needed can be made with low powers of the microscope, and the study so arranged that the more difficult observations with the high power will come at the end of the study and not seriously mar the work if some of the pupils fail in them. With the experience gained by the study of Paramoecium very brief studies of other Protozoans will suffice.

As to the objection in regard to the field work, I feel that it would be well grounded if one must really lose it while working with the Protozoa. But many teachers have found a way out of the difficulty. They take the field trips or stop for laboratory study of perishable live material at opportune times whenever they come. A break of a day or two at a time in the routine is not serious and, in fact, gives a welcome change. Any teacher can devise short lessons for these brief field or laboratory studies of the living animal, then the laboratory notes of the pupils are laid aside until the study is reached in regular order. The impressions

gained by contact with the live animal will not be lost and can be easily gathered up again at the right time. Much more study of the live animal, both in the field and in the laboratory, can be obtained in this way than by any other course.

As to the pedagogical advantages gained by following the order of development from the lower to the higher, I need not say much, for everybody appreciates that it is the logical course. I will mention some of the points that appeal most strongly to me. The lower animals are simple and little specialized and for this reason the attention of the pupils can be concentrated upon the primary conditions of animal life at the outset, a most decided advantage. Then, too, the fundamental principles of zoology are discovered one by one and step by step as the work goes on, not in complex form, but in their simplest form. They are not obscured by a wealth of details as in the case of the higher animals. The pupils become accustomed to handling animals gradually and the drawing work is simple. There is time to enforce and drill over and over again the important topics so necessary for success with beginners.

There has been much objection among educators to receiving elementary zoology into the ranks of subjects preparatory for college. There has been some change of attitude in this respect, but physics is still the only science that is required for admission to college. The reasons given for this attitude are that zoology teaching is not well organized, and that there is no disciplinary value in the work of zoology, therefore it should not be listed as a college preparatory subject.

The remedy for this, I think, lies in our own hands. There is no doubt that the charge that the zoology course was not well organized, was well founded when it was first made, but the conditions are rapidly changing. Formerly zoology was a makeshift subject, and was relegated to almost any teacher who did not happen to have full work. In the best schools now-a-days the biology teacher is specially prepared for his work and often has won his doctor's degree at a university. There is now, also, a number of good text-books and manuals for the teacher's selection. Altogether, there seems to be no good reason why good consistent courses in zoology may not be given, courses that are progressive and give the student an increasing grasp

of the subject as the work proceeds. Whether this shall be done now depends upon the teacher. Let us not as teachers lose sight of the primary purpose of a course in a search for an easy or an interesting road.

There is no inherent reason why a well-planned course in elementary zoology should have not disciplinary value. If zoology is worthy of inclusion in college courses, there can be no good reason for excluding it from secondary school courses, or for saying that it does not have disciplinary value when taught in a secondary school, but is all right when taught in a college. Again, it all depends upon the teaching in the secondary school as well as in the college as to what value the course has. If the course is well planned and the fundamental principles are insistently sought after and enforced it must be of disciplinary value. Such a course need not be dry or uninteresting, on the contrary it will give the pupil conscious power to interpret nature, a much more real pleasure than any superficial course can give. I feel strongly that the logical courses proceeding so far as practicable step by step from the lower to the higher is the best course for the great majority of teachers to use, and that it is a mistake to advocate the irregular course. While, undoubtedly some teachers may plan consistent progressive courses of that sort and carry them to successful issue, it does not follow that it can safely be made a general practice or that it is the best course.

PLANT ACTION IN THE FORMATION OF CAVES AND CLIFFS.

By J. Paul Goode and Otis W. Caldwell.

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Plants are active agents in rock disintegration. The physiographer is well aware of their efficiency in breaking up talus blocks or glacial erratics, by the wedging power of their growing roots. The penetration of roots into the earth is everywhere recognized as a most efficient agent in reducing partially disintegrated rocks into soil. Chemically, too, plants are powerful workers in rock weathering in several of its phases. Indirectly, by furnishing carbon dioxide, in the decay of plant tissue, which

carbon dioxide is readily combined with water to form carbonic acid and arms the ground water with a very powerful solvent for rocks, most conspicuously for limestone. All our great caves, the Mammoth, the Wyandotte, Luray, and others, are due almost wholly to this action. This factor of solution is a larger one than is usually recognized in the general lowering of the continent. Chamberlin estimates that in recent geological times 1200 feet of limestone has been removed bodily from southwestern Wisconsin by solution alone. And not only plants in decay, but living plants produce acids in their growing, which are powerful rock solvents, and which enable the plant to live upon a bare rock surface. Of all such plants the lichens are most effective, being able to establish themselves upon the bare face of the rock, and to maintain themselves sucessfully, if only the light be not too strong or the rock too dry.

Some observations have been made by the authors of this paper upon a special case of erosion, in which lichens and their congeners play a prominent part, and in which it is possible to put their action into direct comparison with other and more conspicuous agents of erosion. The Embarras river, a western branch of the Wabash, which flows through east central Illinois, has in post glacial times cut a trench through the glacial till, and through carboniferous sandstones and limestones, and which, near Charleston, Ill., is nearly a hundred feet deep. The down cutting has practically ceased because of a reduction of gradient to the level of the Wabash, and the channel is meandering rather widely, so establishing bluffs and precipices on the outcurves along either side of the widening valley. This gives tributary drainage lines of very high gradient making them very efficient in corrosion.

In one of these lateral drainage valleys these studies have been made and photographs taken, which accompany this paper. It was noticed that there were cliffs, which could not be referred to planation by the stream. That no cliffs faced north, all north slopes being rounded down to the double curve, convex on the upper shoulder because of weathering, and concave below by reason of deposition—the normal bluff profile. But on southward and eastward facing slopes this curve of beauty is repeatedly broken into by precipices—bare cliffs of sandstone rising from

a few feet to upwards of a hundred. And in the axis of nearly every lesser drainage line, a fall is developed at the junction with the larger stream, these falls usually having a considerable cave underneath. Such falls too, occur in positions which cannot lay any claim to superior planation, or often to any planation

FIG. 1. ROCK FACE WITH EAST AND SOUTH EXPOSURE

at all, by the master stream. Nor is there any difference of structure to be detected in the sandstone, which could be responsible for such a fall; the sandstone of all the region being very uniform in texture and free from any inequalities of structure or composition.

The result of our study shows that all the cliffs, and the caves too, are due to the work of lichens and nearly related plants. In fact, that the formation of the cave is the cause of the cliff.

It will be noticed the plants that are adpated to life on rocks usually do not flourish well in regions of great exposure to direct sunlight and the dessication resulting from such exposure; consequently we usually find such exposed places barren. In places shaded during a considerable part of the day, these plants so sensitive to extreme lighting, may flourish. Moisture and

FIG. 2. SURFACE OF SANDSTONE CLIFF COVERED WITH LICHENS.

Growth takes place from the center of the patch until the entire surface is covered. The upper ledge projects some feet outward from the part bearing the plants, hence this ledge receives direct sunlight; it cannot support lichens of the kind in question.

medium intensity of light are requisite for the plants usually found in rocky places. In figure 1 is shown a sandstone face exposed constantly to east and south lighting. The rock is a firm, nearly perpendicular wall, showing no trace of plant action over most of its surface, and no trace of erosion. Yet at the base of the cliff, where the rock is constantly shaded by adjacent shrubbery the face is more or less completely covered by a growth of lichens.* (Note 1.) The lichens are able to get a footing upon this particular form of rock face before any other plant observed, and can flourish there by means of the absorbed

FIG. 3. MASSES OF LICHENS AND DECAYED MATERIAL PEELING OFF FROM THE ROCK WALL.

* Note 1.—The name of this lichen has not been definitely determined owing to the fact that no fruiting structures have been found. It is probably *Amphilema lanuginosum* Ach. or *Pannaria lanuginosa*, Koerber. It is in a low order of lichens, in which the algal and fungal elements are not so closely related as in most lichens.

water and the materials derived from the rock. Part of the fungal element of the lichen often penetrates some little distance into the interstices of the sandstone, while the algae remain near the surface in a favorable position for chlorophyll work.

The character of the sandstone is quite an element in the problem. It is made up of rather sharp and clean cut quartz grains, very uniform in size, with a scanty cement of limestone, and with limonite enough to give it a cream color. The fungus needs to dissolve only a little limestone to open an interstice and loosen some sand grains. These grains falling down are ready for removal by the wash of rains or the passing stream. Some of the sand grains are caught in the mass of plant growth, and so overweight it, and sooner or later the cushion of lichens is pulled off bodily, leaving the rock face temporarily bare, and ready for the lichen growth to begin anew.

So we have a system of undercutting established through the

FIG. 4. SMALL CAVE SHOWING LICHENS AND OTHER PLANTS AROUND ITS BORDER.

Above is shown a small stream (now dry) which empties over the mouth of the cave. The action of the water is not sufficient to keep pace with the action of the plants.

agency of the lichens, invited by the shade of trees or bushes near, and later by the shade of the overhanging cliff, and also by the greater supply of moisture at the lower level, near the permanent ground water. This undercutting may be carried back into the cliff as a cave, the limit of invasion being fixed usually by the lack of cohesion in the rock above and the weight to be supported. If undermined too far, the whole face shears off and a new face is established some feet farther into the cliff. In such case, the talus, exposed to constant shade and moisture, is soon disintegrated and washes away, and so the cliff is maintained.

When these lichens have grown for some time, the products of their decay, together with the disorganized rock, form suitable food material for numerous other plants that soon establish themselves upon the lichen mat. Following the lichens were found among the algae, *Pleurococcus, Gleocapsa, Anabaena, Scytonema.* Several species of moss were found. The liverwort, *Conocephalus conatus,* was very common in places where constant shade obtained. Several species of ferns and occasionally seed plants are found, following the growth of the plants mentioned. The rhizoids of the liverworts and mosses, and the roots of the ferns follow paths opened up by the fungi of the lichen, and assist in the breaking down of the stone.

When the process of undercutting is begun, as above described, the overhanging wall increases the shade, evaporation is reduced and a more favorable temperature is established and the incision goes on at a much more rapid rate because of the more genial conditions. In this way numerous small caves are developed. The depth is limited only by the inability of the plants to adjust themselves to a decreasing supply of light, and by the lack of cohesion of the sandstone. A more constant supply of moisture also is a determinant. Thus the deep caves under the water fall of the little tributary drainage lines are explained.

Although the streams in these gullies rarely carry large quantities of water, being wet weather streams, there is almost constantly some slight drainage from the shaded soil of the valley walls, which dribbling over the face of the sandstone, gives a much more energetic life and a longer season of growth to the colonies of lichens and other plants under the brow.

So the cave maintains itself, and the cliff recedes and all the wash of storms, and the pry and thrust of wedging roots and freezing water are not equal in their work of degradation in these special conditions, to this insidious, gnawing lichen. And the question is raised whether we shall not find on more careful study, that much of the real work of undercutting in cliffs generally, is to be properly attributed to these extremely efficient workers. Shall we not find their fine hand in evidence in the curious, concave faces of the "navy yard" in the Dales of the Wisconsin river and all along the cliffs of the Mississippi. And in the southwest, in the undercut precipices where the cliff-dwellers found a safe retreat from the wild tribes of the plains; and in the cliffs of the Vezere, where the prehistoric Frenchmen made their homes.

FORCE AS AN ENERGY FACTOR.

By A. H. Sage.

State Normal School, Oshkosh, Wis.

The discussions that have appeared in this journal recently by Professor Crew and Professor Stewart relative to the nature and peculiarities of the law of force, $f=ma$, have been of interest to me because I have found my students experiencing the difficulties mentioned. There is a considerable number of similar difficulties pertaining to the formulated law of physics, which makes a thorough appreciation of these laws difficult for the beginner.

The same obscurity or confusion, for example, as that referred to above is seen in the use of f and v in the law of momentum, $ft=mv$, in which v must be taken as the velocity acquired through the action of the unbalanced force f, and not as including any initial velocity which the mass may have possessed; that is, as Newton puts it, it is the "change of momentum" and not the total momentum of a body that measures the impulse.

Another case along the same line which my students meet is the difficulty of accounting for the error in the calculation of energy from the law, $E=fs$, when the mass on which the force acts possesses an initial velocity, i. For example, a 20 gram mass

having an initial velocity of 42 centimeters is acted on for 6 seconds by a force of 80 dynes. Then

$F=ma=80=20a.$

$a=4$

$v=at+i=4\times6+42=66$ cm.

$s=\frac{1}{2}a^2+it=\frac{1}{2}\times4\times6^2+42\times6=324$ cm.

$E=fs=80\times324=25920$ ergs.

$E=\frac{1}{2}mv^2=\frac{1}{2}\times20\times66^2=43560$ ergs.

Now, it is readily seen that the difference in the two results is due to the energy of the initial velocity which is included in the 43560 ergs, but not in the 25920 ergs calculated from the law $E=fs$. Nevertheless, the student who has just calculated the value of s from the law of acceleration, $s=\frac{1}{2}at^2+it$ usually replies that the initial velocity was included in the calculation of fs as well as in the other case since the space s contains the result of this initial velocity. Of course, the error of his reasoning lies in the fact that while the functioning capacity of a force is dependent on the space through which the force acts on the body, it is independent of the velocity of the body. Therefore, while the force really acted through a greater space on account of the initial velocity, its capacity for imparting energy was thereby increased in proportion to the increase in the space covered, but not in accordance with the extra velocity which caused that increase in space.

The appearance of this difficulty in the student's course affords a suitable setting for the elucidation of a further application of the law, $E=fs$, in such cases as that of the steam pressure against the piston of an engine. In such cases the body impressed (eg., the piston) is not a free body. Because of the resistance, the piston does not move through the space it would cover if free. Here we see the reverse application of the principle of conservation of energy exemplified above. In that case the increased space but not the increased velocity was a factor in the transference of energy; here, the decreased space covered, but not the subdued velocity, counts in the calculation of the energy imparted. From a physical point of view, it is such considerations as these that lead to the statement that $E=fs$ is the law of work, while $E=\frac{1}{2}mv^2$ is more strictly the true expression of the law of energy.

Every teacher in the course of his experience develops excellent methods of presenting some of these difficult matters to his classes. These pages afford a very suitable agency for the exchange of these acquisitions, and they are certainly needed by most of us. Perhaps, others like myself have hesitated to put in print their own petty experiences in these connections lest some technical inaccuracy of expression or detail make the endeavor seem crude or unscientific. But I am confident that any critical suggestions that may appear in these pages will have only helpfulness for its aim. It will be a great pleasure to me to see contributions along these lines appearing from time to time.

CORRELATION OF MATHEMATICS WITH BIOGRAPHY, HISTORY AND LITERATURE.

By Jos. V. Collins.
Stevens Point, Wis.

In the recitations of mathematics, especially geometry, the mind is usually given up to an exercise of pure thought. As a relief during the progress of the recitation teachers often interject extraneous topics. It is better, of course, to give something that relates to the subject and which is calculated to stimulate the class to their best endeavors. Perhaps the finest material available for use for such object is the experiences of men who figure prominently in the history of literature or science studies of the student.

If a boy who is not particularly interested in geometry but who is intensely interested in, say Washington, through his study of history, learns that Washington was once a student of the same branch, and its study early developed for him into a means of earning money to supply his mother's lack of funds, he may be led to take a greater interest in the subject. Or if another who has trouble with his geometrical demonstrations, but who is a great admirer of the poet Longfellow, learns that the latter found more difficulty in mastering the hard problems of mathematics than he did in any other of his studies, but who nevertheless never ollowed himself to come to class without thorough preparation, he also mao be stimulated to more faithful endeavor.[1]

1 Life of Longfellow edited by Samuel Longfellow, p. 28.

It is not easy always for the individual teacher to collect a stock of information available for such use, but some familiarity with this field of interest may easily become a valuable asset to the teacher. The following bits of the biography of eminent men will give some idea of what the field contains to those who may never have looked into it before. At the end of one papers. The following passages from Nicolay and Hay's Life hundred and fifty years Washington's work as a boy in school especially in mathematics, is doubly interesting to us, first on account of what he became, and also on account of the kind of school work he did. He attended a school kept by a Mr. Williams and studied mathematics as far as to surveying; indeed, he remained two years longer in school in order that he might study the latter subject.[2] Fortunately there remain to us some of his school note-books, which show, as President Woodrow Wilson says, that he studied to master his subjects. His note-books, which were filled with rules, formulas, diagrams, and geometrical notes of surveys, all showed the marks of the "neatness and accuracy" which were characteristics of all his work both in school and in after life. Not only did these books contain what was expected of him in his special line of work, surveying, but they also included copies of all kinds of commercial paper and legal forms, which makes plain that his interests were broader than that of mere numerical calculation.[3]

Perhaps the most interesting example of the part mathematics has played in the intellectual equipment of a great man is found in the case of the immortal Lincoln. As is well known Lincoln never obtained in school any training beyond that in the common branches—all told about a year's work. His study of geometry was undertaken after he had practised law for a considerable time, had acquired a reputation as a lawyer, and after he had served a term in the congress of the United States. It must have been no small undertaking for a man of Lincoln's previous education, and at the same time prominence in his profession, to take up the regular formal study, by himself, not of one of the diluted geometries in current use at the present time, but of the original Euclid with all its difficulties. Who will doubt

2 Life of Washington, by Woodrow Wilson, p. 51.
3 Life of Washington, by Henry Cabot Lodge, p.

that a study, such as geometry is, undertaken under such circumstances, and with such an aim, bore rich fruit in his after work; as, for instance, in the Lincoln-Douglas debates, and in state of Lincoln recounts the facts. In that briefest of all biographies which Mr. Lincoln wrote for Jesse Fell upon three pages of note paper, he sketched the period at which we have arrived in these words: 'From 1849 to 1854, both inclusive, I have practised law more assidiously than ever before.' . . . . . It was at this period that he gave a notable proof of his unusual powers of mental discipline. His wider knowledge of men and things, acquired by contact with the great world, had shown him a certain lack in himself of the power of close and sustained reasoning. To remedy this defect, he applied himself, after his return from congress to such works upon logic and mathematics as he fancied would be serviceable. Devoting himself with dogged energy to the task in hand, he soon learned by heart six books of the propositions of Euclid, and he retained through life an intimate knowledge of the principles they contain."[4]

A newspaper paragraph often met with states that Mr. Lincoln in conversation recounted the circumstances under which he undertook the study of geometry. The story begins: "A man who heard Mr. Lincoln speak in Norwich, Conn., some time before he was nominated, meeting him on the train next day inquired where he acquired his wonderful logical powers and acuteness in analysis. Lincoln replied: 'It was my terrible discouragement which did that for me. When I was a young man I went into an office to study law. I saw that a lawyer's business is largely to prove things. I said to myself, 'Lincoln, when is a thing proved?' That was a poser. What constitutes proof? Not evidence: that was not the point. There may be evidence enough, but wherein consists the proof?" The rest of the story recounts how he learned to prove things by studying geometry.

This story, especially the last part, seemed to bear the earmarks of being too "well-turned," and of having been embellished and enlarged by some professional paragrapher, and so

4 See Century Magazine for Feb. '87, pp. 536, 537, or Nicolay and Hay's Life of Lincoln for this period in Lincoln's life.

the writer wrote to Secretary Hay and to Miss Tarbell, enclosing the clipping, and received the following replies.

Greenwood, Thomasville, Ga., Feb. 1, 1904.

Dear Sir:

The passage you quote from me I had from Mr. Lincoln himself. The newspaper story you inclose is the same thing, amplified and padded by imaginary quotations. These conversations with himself are not in the least characteristic of Lincoln.

Yours very truly,

JOHN HAY.

141 E. 25th St., New York, Jan. 14, 1901.

Dear Sir:

Replying to your inquiry concerning Mr. Lincoln's study of geometry, I believe it is true that he did study the subject after he began to study law. I think indeed that it was after he left congress in 1849. He did this, I am convinced, not so much for the sake of the law, as the story would show, but because he felt deeply at that period the need of a better education. It was not only Geometry, but History, Literature, and German that he applied himself to in his leisure hours. He kept up this study outside of his profession until he threw himself into the anti-slavery struggle. After that began, I doubt if he did much extra study.

Yours very truly,

IDA M. TARBELL.

The part the study of mathematics played in the life of Napoleon is rather striking. Curiously enough, Washington, Lincoln and Napoleon each studied mathematics with his own practical end in view: the first to make of himself a surveyor, the second, a reasoner, and the third with the very definite idea of making of himself a great general. Napoleon's particular aptitudes, says Professor Sloane in his Life of Napoleon (Century Magazine for Nov. '94, p. 25) were mathematics and history and geography. M. de Keralio reported him as "Always having been distinguished for his application to mathematics." In August, 1783, in his fifteenth year, he shared the first prize

It is quite within the realm of the possible that there are men living in Illinois or elsewhere who could give us some details of this outside study, especially of geometry. Such information would be both interesting and welcome.

in mathematics. At the artillery school he was thoroughly trained in mathematics and geography. "Towns cannot be fortified," writes Professor Sloane p. 30, "nor camps entrenched, nor any of the manifold duties of the general in the field be performed without the science of quantity and number." Spelling, grammar, rhetoric, philosophy, were of no particular concern to him: mathematics having a practical bearing on the art of war were matters of special interest.

What is true of Napoleon as regards his interests in mathematics is equally true of our own General Grant. "Grant," recalls a school-mate of his, "was strong in mathematics. I studied algebra with him, and I remember that he would never let Carr White or me show him the way to do problems, but always wanted to work them out himself." "He had a way," says another, "of solving problems out of rule by the application of good hard sense." When Grant was at West Point, he wrote home on one occasion. "We are having tremendous long and hard lessons in French and Algebra." He was recognized at West Point as a good mathematician, and in the examination was surprised to find he had obtained a very good place in the class in mathematics and kindred subjects. Towards the end of his course he formed the idea that he should like, when he got through, a detail as an assistant in mathematics at West Point. Then he hoped later to get an appointment as Professor of Mathematics in some college, which would become his life work. As is well known our country got a very considerable uplift in mathematics through the bringing into West Point of some able French mathematicians, and later selecting young West Point graduates for its college chairs. Doubtless Grant knew of this and so was led to form the plan referred to. Grant stood fifteenth in mathematics in a class of sixty in algebra, geometry, trigonometry, and analytics, and tenth in a class of fifty-three in the advanced mathematics.[5]

The lives of others of our presidents besides those of Washington, Lincoln, and Grant contain interesting items concerning their work in mathematics. Thus "in mathematics Jefferson[6] was at his best, and he could read off the most abstruse processes

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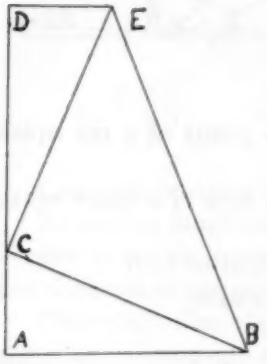
5 See Hamlin Garland's The Early Life of Ulysses S. Grant (McClure's Magazine, Dec. '96, Jan. '97.) and Grant's Memoirs.

6 See Watson's Life and Times of Jefferson, p. 19.

with the facility of common discourse. This study he kept up as long as he lived: and he delighted in applying its principles to anything and everything."

The story of how President Garfield when a boy in college worked out an original demonstration of the Pythagorean theorem has become well-known. It ought to be an interesting exercise to a class. Assuming that the demonstration is not generally known, we take the liberty of giving it here.



Let ABC be a right triangle. On the hypothenuse CB describe the half square BCE, and from E draw DE perp. to AC produced.

Area $ABED = AD \times \frac{1}{2}(DE+AB)$
$= \frac{1}{2}(AC+AB)^2$

But area ABED = area ABC + area DCE + area ECB
$= \frac{1}{2}\overline{BC}^2 + (AC \times AB)$

Therefore $(AC+AB)^2 = BC + 2AC \times AB$

whence $\overline{AC}^2 + \overline{AB}^2 = \overline{BC}^2$ Q. E. D.

(*To be Continued.*)

A CULTURE COURSE IN MATHEMATICS.*

By T. M. Blakslee.

Central College, Central City, Nebr.

PART I. SLANT AND SLIDE.

SEC. I. ELEMENTS DEFINED. (A). RAYS.

An element of a line is a point.

An element of an angle is a half-ray, (spoke).

The zero-point of a line is the origin.

The zero-spoke of an angle is the origin.

Any other point of the ray has a slide equal to line from origin to point.

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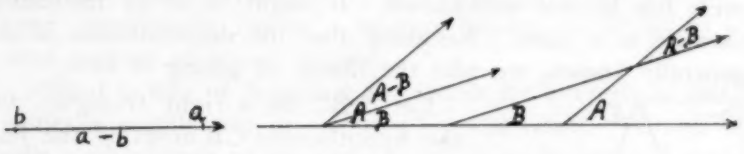
*With this number we begin a series of papers based on Mr. Blakslee's lecture notes on a general culture course prepared for freshmen students of Des Moines College, Des Moines, Iowa. They are so filled with valuable hints as to ways in which high school teachers may infuse modern notions and new methods into their work and so suggestive as to ways of introducing the ideas and spirit of the more advanced mathematics into secondary algebra, geometry and trigonometry so as to be truly helpful to their teaching, that we have felt constrained to give our readers the benefit of them. We have accordingly arranged with Mr. Blakslee to run them serially through subsequent numbers of School Science and Mathematics. The Editors.

Any other spoke of the angle has a slant equal to the angle from the origin to the spoke.

The foot of a ray is its join with origin.

We might, but do not say: The foot of a point—

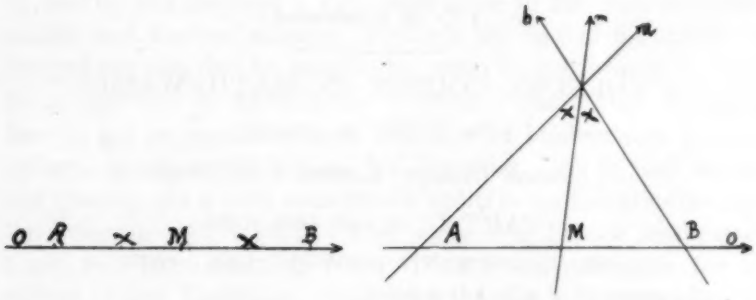


1. The distance interval between two points of a ray equals the difference of their slides.

2. The angular interval between two rays of a plane equals the difference of their slants.

NOTATION. The slant of ray a is A; that of b, B.

SLIDE OR SLANT OF MID-ELEMENT.



The difference-mean of two numbers equals their half sum.

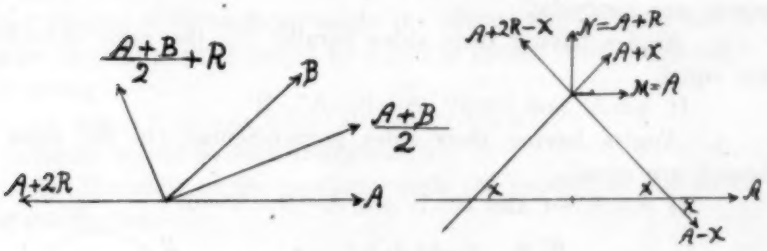
If $M-A=B-M$, $M=\frac{1}{2}(A+B)$

Since numbers can be represented either by the slide of a point, as in a scale, or by the slant of a spoke, as in a clock, we say:

The slide of the mid-point of a line equals the half sum of the slides of its bounds.

The slant of the mid-ray of an angle equals the half sum of the slants of its bounds.

What theorems do the following figures prove?

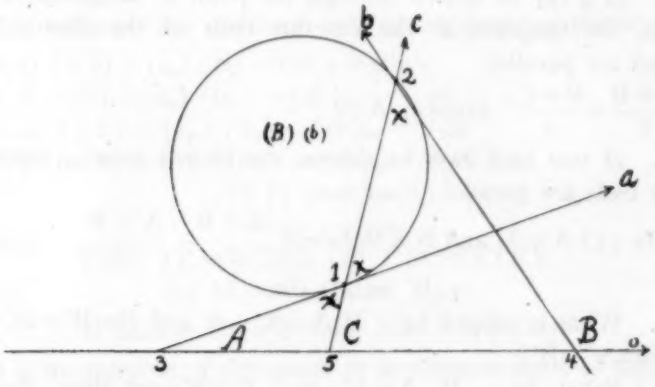


(B). CIRCLES.

Concyclic points are on a circumference.

As no two tangents to a circle have the same slant, it is convenient to use the same symbol to denote both a point of a curve and the slant of the tangent at that point.

Theorem. The slant of a chord equals the average of the slants of the tangents at its bounds.



$\triangle 135$ gives $C = A + X$.

$\triangle 245$ gives $C = B - X$.

$\therefore C = \frac{A+B}{2}$

This method will prove all theorems that the author has met concerning the angle between rays that are chords or tangents.

Those given are very easy. Test on hard ones.

EXAMPLES I.

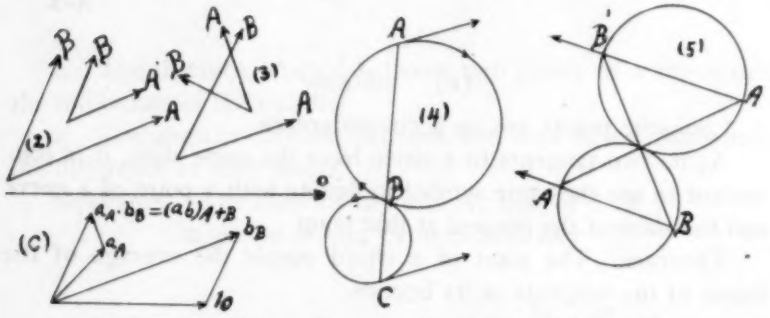
1. If four circles are tangent, two and two, the contact-points are concyclic.

2. Angles having their sides parallel (in the same sense) are equal.

If $A=A'$ and $B=B'$, $A-B=A'-B'$.

3. Angles having their sides perpendicular (in the same sense) are equal.

If $A=A'+r$ and $B=B'+r$, $A-B=A'-B'$.



4. If a ray be drawn through the point of tangency of two circles, the tangents at the exterior ends of the chords thus formed are parallel.

$\frac{A+B}{2}=\frac{B+C}{2}$ Hence, $A=C$.

5. If two such rays be drawn, the chords joining their exterior ends are parallel

By (5) $A=A'$ and $B'=B$, hence $\frac{A+B}{2}=\frac{A'=B'}{2}$

ORIGINALS.

1. What is proved by: If $A=A'+2r$ and $B=B'+2r$, then $A-B=A'-B'$?

2. What by: If $A=A'$ and $B=B'+2r$ then $A-B=(A'-B')-2r$?

3. What by: If $A=A'+r$ and $B=B'-r$, then $A-B=(A'-B')+2r$?

(c). GEOMETRIC PRODUCT.

Geometric multiplication consists in doing to the multiplicand, (as regards slant and slide) what must be done to the initial unit 1_0 to obtain a multiplier.

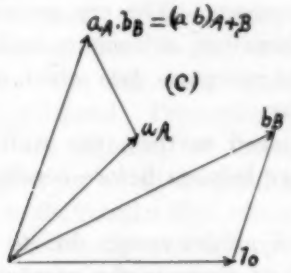
Problem. To multiply a sub A by b sub B.

Now a sub A is the vector having the slide a and slant A. b sub B can be obtained from 1_0 by stretching it in the ratio b:1 and turning it through an angle B. Hence the vector a sub A must be multiplied in length by b and be turned through an angle B giving:

(a sub A) (b sub B)=(ab) sub (A+B).

Easily solved by sim. triangles.

I. The slide of the product equals the product of the slides of the factors.



II. The slant of the product equals the sum of the slants of the factors.

This includes the ordinary rule of algebraic multiplication.

$(+a)\,(+b) = (a_0)\,(b_0) = (ab)_0 = +ab$
$(+a)\,(-b) = (a_0)\,(b_{2r}) = (ab)_{2r} = -ab$
$(-a)\,(+b) = (a_{2r})\,(b_0) = (ab)_{2r} = -ab$
$(-a)\,(-b) = (a_{2r})\,(b_{2r}) = (ab)_{4r} = +ab$

(To be continued.)

THE TEACHING OF GEOMETRY.

By Miss Clara A. Hart.

Wadleigh High School, New York City.

It is the purpose of this paper to investigate some of the conditions which militate against obtaining the best results in the teaching of geometry in seconday schools, to suggest possible means toward remedying existing imperfections, and to outline the methods which obtain or are in process of development in the best American schools.

It is no new complaint that students are unable to apply to other sciences the principles which they have presumably had the opportunity of mastering in mathematics, and the complaint

is becoming more and more insistent. Moreover, the colleges and universities are awakening to the recognition of their own responsibility in crystallizing the standard of the lower schools, and the signs of the times indicate a widely spreading change in sentiment as to what shall constitute desirable preparatory work for college; this change should soon be felt in altered requirements for college entrance, and as the factor of general intelligence and power to apply secondary school mathematics is increasingly insisted upon in college entrance examinations, the secondary schools must offer broader and more practical training to meet these requirements. The cry comes from the departments of physics, chemistry, astronomy and physiography that students are unable to recognize data which are transferable into mathematical formulae.

Science is not indeed to them the stuff that problems are made of, and they are helpless before conditions which seem to them entirely new.

Now this state of affairs seems due to several causes and perhaps the greatest of these is the narrowness of the teacher and his inability to rise above a system which seems to approve the relegating to separate hermetically sealed compartments the subjects which belong to elementary and secondary school curricula. It is not unusual that a student is surprised to perceive a relationship among the various subjects which he is pursuing. It is, however, quite natural that this should be the case. In the first place his knowledge of what he has learned is necessarily superficial to a great extent, and very likely he has seen but one aspect of the subject. Who would expect even an observant adult to recognize in unexpected surroundings and in an entirely different dress a person who is but an acquaintance. We must know an individual very well before we are able to recognize him at a mere glimpse. Now it is precisely this failure to recognize that is the difficulty with the majority of young students. They have perhaps mastered theorems in geometry to the extent that they can draw a figure somewhat like the one in the text book, letter it differently and demonstrate it without slavish adherence to the text. They may even devise different means to attain the conclusion, but the matter then drops into its pigeon-hole and is expected to stay there. Dr. Osgood, of Harvard, says: "A student's ability to prove a proposition is no assurance that he

knows it. The test as to whether he knows it is whether he can use it." Work should be more than merely receptive as soon as the art of rigorous demonstration has been grasped and appreciated, or even before; otherwise it becomes dull and unprofitable.

Most text-books make no attempt to give new aspects to matter once threshed over, to throw different lights upon it, to modify it by new environment, and then to *use* it to develop new relations and to discover new truths. Ability to do original work is the true test of the student's knowledge and proper understanding of the subject. The difficulty which is too often experienced with original work is due largely to the poor arrangement of the exercises and their separation from the theorems upon which they depend. Principles no longer fresh in the mind of the student are required for their solution. They are usually heaped together in an ill assorted pile at the end of a book. With no key to the puzzles thus offered, only the brightest students will have the courage to attempt their solution, and these will trust largely to hitting upon a method of proof in some happy moment of inspiration. Thus is lost the great delight as well as the great benefit of original work, which should enlarge and round out each demonstration given in the text. It is as if the main propositions were but one element of the rainbow hues which must be complemented by many others before the white light of a full comprehension is attained. In thus attaining the clearer vision, misconceptions are detected which might have remained concealed with a narrower range. Innumerable exercises offer as illustrations. To take a simple case which may be applied two weeks after taking up the study of geometry, suppose the student has taken up a few elementary propositions among which were: "Two triangles are equal if two sides and the included angle of one are respectively equal to two sides and the included angle of the other," and "Two triangles are equal if a side and the two adjacent angles of one are respectively equal to a side and the two adjacent angles of the other," the proof by superposition having been made clear by cutting out paper or cardboard figures to apply to the board. With the suggestion that to prove lines and angles equal it is generally expedient to try to prove triangles equal, the lines or angles being corresponding parts of the equal triangles, the student will by a little ques-

tioning soon discover that the line bisecting the angle at the vertex of an isosceles triangle divides the figure into two equal triangles, that the base angles of the isosceles triangle are equal, that the bisector of the angle at the vertex is perpendicular to the base and bisects it, etc. If colored chalk be used to mark the equal lines an additional interest may be awakened and new relations in figures may be more rapidly discovered. Thus at this stage if an isosceles triangle be drawn colored as indicated here and without verbal comment save that equal lines or equal angles are indicated by the same color, the student will discover at once that AD=AE, that angle ADB equals angle AEC, etc. (Fig. 1).

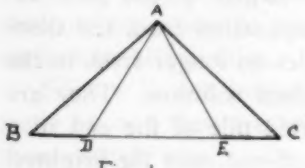


Fig 1

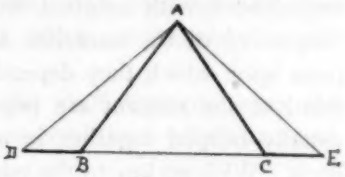


Fig 2

He should then be required to make a statement regarding the figure (a theorem) and to give a formal proof. He may now be led to generalize by asking whether D and E must be limited to the line segment BC, or whether they may be taken on the *line*. The student will at once draw the figure thus (Fig. 2):

Many other exercises may then be given by the teacher or suggested by the class. Thus, the equal distances may be measured on the equal sides from the vertex, as shown in Fig. 3, and equalities may be discovered, the case being extended as indicated by Figs. 4 and 5. Care and system in the lettering of figures may here be encouraged by asking whether one proof may serve for the three figures.

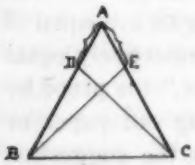


Fig 3

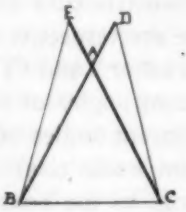


Fig 4

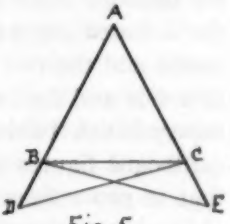


Fig 5

(To be continued.)

TENDENCIES TOWARD THE METRIC SYSTEM.

By Hon. James H. Southard.

Chairman of the House Committee on Coinage, Weights and Measures.

There are few unbiased people who will contend that our system, if we may call it a system, is satisfactory. It is, in fact, very much otherwise.

The decimal system is gaining ground every day, and this may be said without any fear that it will be successfully contradicted; there is no country, no nation in the world, having a decimal system of weights and measures, or currency, where there is the suggestion of a change. There is no country in the world where they have not a decimal system of weights and measures, or of currency, where there is not constant agitation in favor of a decimal system. Repeatedly the Colonial Premiers of the British Empire, the Representatives of her Chambers of Commerce, and her select committees appointed by the House of Commons, have declared in favor of the compulsory adoption of the Metric System; and, when today we speak of a decimal system, so generally has the French Metric System come into use, that we mean that system.

The Metric System is something more than 100 years old. During that time it has traveled around the globe. More people use it today than use any other. Its progress was slow at first. It took France, the country in which it originated, a long time to adopt it. It is not strange that this should be true. As a legacy from feudal times she had many systems of weights and measures, and this was the case with Germany and other countries at a still later date. Every feudal baron, as far as possible, had his own weights and measures and his own system of coinage. Feudalism passed away, but some of the customs, habits and practices remained longer. There was much confusion, of course, but there was comparatively little commerce. People did not get far away from home. One man traded with another who understood his weights and measures, and they got along, in a way. A point is sometimes made of the fact that it took France so long to adopt the system. I think it marvelous

that she adopted it with so little effort. Every country that has tried it since has accomplished it with less effort. Mexico tried it only a few years ago, and today the Metric System is employed there as universally as what we call the English System is here. It is complained that even in France where the Metric System has been in use the longest, other measures and weights are sometimes used.

Mr. Dale, in a long drawn out argument in his book "The Metric Fallacy," says that there is a great confusion of weights and measures in the textile industry in France. How could it be otherwise? This industry began there before the Metric System. France is a close neighbor to Great Britain, and has always exerted a dominating influence in the textile industry. How could one expect anything but confusion, especially where the industry is carried on as it is and has been there? Indeed, it would be too much to expect uniformity anywhere under such conditions.

I have heard a good deal and read considerable about weights and measures during the last few years, and I think it can be said truthfully that the Metric weights and measures are as universally used in what are known as Metric countries as our own system is here, or the English System is in England. Today everything tends toward uniformity. Modern improvements are the cause of it. A hundred years ago a few people in the world had just begun to think of railroads and telegraphs. Robert Fulton hadn't yet given us the steamboat. It was then farther from Boston to where Chicago now stands than it is today around the world. It was a long journey across the Atlantic. We had a few hundred Post Offices distributing a few hundred thousand pieces of mail annually. We had not yet dreamed of the telephone, which now goes everywhere. The people of Pennsylvania were strangers to the people of New York. There was very slight communications between the people of our largest cities and towns. New York was not as large then as Toledo is now. There were few settlements of any kind west of the Ohio River.

Some of the countries of Europe were older and more thickly populated, but much the same conditions existed there. Modern means of transportation and communication were the dream of

the few who had little means of letting others know what they thought. Now two hundred and ten or twenty thousand miles of railroads intersect every part of the country. They have nearly as much in Europe. Two hundred thousand miles of cable, running under every sea, and more than ten times as many miles of land telegraph permit the people in every part of the inhabitable globe to converse with every other people in a universal language. A man can sit at his own fireside in Boston and talk to his neighbor in San Francisco, each unmistakably recognizing the voice of the other. One may breakfast in New York and dine in London a week later.

Sailing in mid-ocean, I am told the passengers may enjoy their morning paper, printed from news "flashed on invisible waves over a thousand miles of sea."

From a few hundred Post Offices, distributing a few hundred thousand pieces of mail, we now have seventy or eighty thousand distributing ten billion pieces of mail annually, coming and going everywhere wtih a certainty, speed and regularity made possible only by our system of railroads and telegraph.

In 1833 there were six daily newspapers printed in New York City, with a combined circulation of 18,000 copies. Now there are printed and sold in that one city more than 2,500,000 copies each day. News is received from Japan and "printed and read here before it happened there," and on the same day on the pages of the same paper we find messages from Australia, Pekin, and the sources of the Nile.

These are only a few of the things that have been happening and they are only in line with other things that are going to happen. Already the speed of an electric car has reached the limit of one hundred and fifty miles per hour—a great improvement over the steam engine. Wireless telegraphy is only in its infancy, and who can say that airships carrying their own power will not be as common in fifty years as steamships are today?

This means that the nations are drawing closer together, whether we perceive it or not, and all this tends to unify language, thoughts, customs and manners. Instead of remaining provincial everything is becoming national and international. We have our international associations, not possible a short time Union, International Trades Unions, International Arbitration

Associations, International Bureau of Weights and Measures, our International this and our International that.

When we first adopted a decimal system of coinage to take the place of pounds, shillings and pence, it was unpopular. How is it now? The English have been over here, and have found out how much more rational our money system is, how much of an improvement it is, and their own system is becoming unpopular even at home. They resolve against it every chance they get, and in favor of a change, but it is hard to get a move on and make the change.

Most Americans are getting to see the disadvantages of our cumbersome system of weights and measures, but they are just like the Englishman with his pounds, shillings and pence. He resolves against it and it ends there. He is like a fellow with a bad habit. It requires some self-denial and some effort to leave off the old practice and he temporizes. If he is growing, however, in the course of time he undertakes the reform and accomplishes it. That's what they are going to do in England and it is what they are going to do here. We have all heard the story of the boy who carried the meal in one end of the sack and a large stone in the other to balance it. In the course of time he found it better to divide the meal and find the balance by putting half of it in each end of the bag. It took a good deal of persuasion to get him to see that it was a better way to carry the meal, and he continued in the old way for a while, after he saw the advantage of the new way, because his father and his grandfather had done so. This illustration shows how the world is progressing. Maybe it will be a long time before we shall have a universal language, if we shall ever have it. It will probably be a long time before we shall have a universal currency, although the world is fast moving to a single standard of value, which is the first long step toward it. There is no good reason why we should not have a universal language in weights and measures the world around and from the equator to the poles. There are many peoples and many languages differing more or less widely from each other. There are many different systems of money, many of them having widely distributed circulations. There are, practically speaking, but two systems of weights and measures, or one system and one jumble. To some extent either

is used almost everywhere. It is plain that one of these systems must give way to the other. Which is going to become universal, the one that gives satisfaction wherever it is tried, or the one that is continuously complained of wherever it is employed.

The Metric System is coming, it is here and here to stay. All the Dales and all the Halseys are but the fly on the wheel. They cannot stop its revolutions. They might as well try to impede the progress of a mighty glacier as to stop the movements of the Metric System in its advance toward universal adoption.

FORESTRY IN THE PUBLIC SCHOOLS.

Suggestion as to a Way to Interest Children in the Practical Side of Forest Growth.

By A. Neilson.

Some instruction in forestry, I believe, would be of great benefit to the children in our public schools, without working any great hardship on the teachers. I am painfully aware that a lot of hands will be raised in holy horror at the idea of introducing a new study and I will not wonder at it for in the present day, *real* workers are, as a rule, overworked. But I think it very important to teach children something about nature in a practical way and, in my opinion, the best thing to do is to teach them something about practical forestry.

The average child in the country grows up with the impression that country and nature simply means dust, mud, and crops. The dust and mud on the walks to the school house, the crops after he gets home, or during his holidays, when his father has to be helped out. When I was a small boy and walked to school in Harford county, Maryland, about all I knew about nature was that it produced sassafras roots, and I used to dig them out of the roadside. I was never taught anything about botany, and often sat in the school room looking out of the window at all kinds of tree growth, without having the slightest idea of what it all meant. Even while I was quite small, I took up nature study, on my own account, because I had a natural inclination for that sort of thing, and I have kept at it ever since, and now, when walking or driving in the country, every kind

of growth presents some matter of interest to me. But I sincerely regret that I was taught nothing of nature at the various schools to which I went, for what one learns at school, even in a primitive way, holds on through life, to a certain extent. Studies that I hated and shunned in every way, have still left their imprint, and even the limited knowledge I got of these distasteful ones has been in after life of great use to me. It will be the same with the study of forestry. Some children will be enthusiastic over it, some will dislike it, but it will leave its imprint on all. When a child grows up and has occasion to plant trees, he or she will remember their early teaching, and not be absolutely in the hands of the nurseryman. Some teachers will not appreciate or like this new study, but they must be teaching things now that they do not like nor have any interest in. To the new study I advocate I offer the solace of *outdoor work*. It takes the teacher and the children from the bad atmosphere of the school room into the clear, pure atmosphere of outdoors, where it will be simply play while the studies are going on. I trust this argument will do away with the usual objections offered to the introduction of a new study. I am simply suggesting a little more sunshine for the otherwise dull life of the school room.

The country child is fairly engulfed in everything that is attractive, yet has no conception of it. The city child is taught a great deal about the country, and he is thoroughly posted as to his city life, too; but he will do any amount of work in anticipation of a day in the country, and when he gets there, will often be able to tell his country cousin all sorts of things about the trees, shrubs and flowers, that will make the latter open his eyes.

The country child, unfortunately, does not know either his own life, or the city life. He little dreams of the pleasures that are lurking for him in the woods, fence rows and fields. Help him, give him some instruction as to the ways of nature and he will be happy and go on and learn the rest in his own way.

I do not expect teachers to become expert foresters, nor is there any occasion for going into forestry details. What I suggest is simply a practical start in a small way in forest education. The salient and simplest forms of forestry must be taught out of doors, among the trees and bushes. What I advocate at

the start is to teach the children how to distinguish the various trees and shrubs, teach them their habits, growth, etc., purpose for which the wood is used, and the families the different trees belong to; teach them how to dig up a tree and how to replant it, and how to raise it; how to plant nuts and raise trees from them. This is what I would suggest as a beginning. Really, the starting of an "Infant Class" in forestry.

My idea is, that each school shall have a small nursery, say one-fourth of an acre or even less. This is to be fenced in. Nearly all the school lots adjoin some farm, and it is entirely probable that the owner of the farm would lend this much land to the school commissioners, who could fence it in at a cost of say, five dollars. And no doubt the farmer would contribute the plowing and preparing the ground so that the children could take hold of it and grow the trees. Each school would be furnished with a shovel, hoe, and iron rake. There is, as a rule, in every country school a few boys big enough to wield a shovel; these boys would do the heavy work.

I would suggest giving two to four hours a week to forestry work, the teacher selecting fit days. In the spring, from the middle of March to the middle of May, would be the planting time, and in the fall, October and November. During these periods the teacher would take the children to the nearest woods and dig planting. The trees the teacher would get would be the smallest seedlings, as small as six inches high. These would be planted in the nursery, and during the other months, when fit, the children could be set at work in the nursery caring for it. The nursery will take care of itself during the holidays and during the off planting season. The teacher would also take the children to the woods and give them little lectures on tree matters.

The teacher would not have to be an expert to do all this. I propose that each teacher be given a "tree book," for there are several very good ones to be had, that explain very fully to beginners in arboriculture. There should be purchased by the school commissioners a few dollars worth of very young seedlings from some nursery, so that the instruction will not be confined entirely to native local trees.

A large number of trees can be grown on a nursery of one-fourth of an acre, and giving three years as the age of removal

from the nursery, the plantings should not be more than a third of the nursery area each year. When the trees, at the end of three years, must be taken up, they can be given to the parents of the children, or can be sold. If sold, the money would go to the school to establish a library or for other useful purposes.

I think in a short time after the study is taken up, there will be quite a rivalry among the schools, over their nurseries.

I do not know how much time can be spared from the regular school studies for forestry. A long time on one day would be better than a short time on several days, and the day must be selected each time by the teacher.

If the expense of fixing the fence around the nurseries, getting the tools, books, etc., is more than the commissioners can take for all the schools, I would suggest the selection of some schools, best situated for the purpose. In this selection of schools it would probably be best to take them where the teachers rather like this kind of study; then these schools would be an example for the others, and in course of time this study would be taken up by all.

I estimate that the money required for the introduction of the study of forestry for each school the first year would be about $17.25, made up as follows:

Fencing in the nursery	$5.00
Purchase of outside trees	8.00
Two books	2.00
Pamphlet marking directions	.25
Tools	2.00
	$17.25

With this capital invested, there would be no more expense, except the purchase each year of say, about $5 worth of outside trees. No sales can be made from the nursery for about three years, but after that, each year will produce its crop of several hundred trees, and they would be sure to produce an income of $25.00 per year or more.

While the instruction in forestry is going on, a lot of wild flower study will naturally come in, and will not interfere.—*Forestry and Irrigation.*

SOME DIRECTIONS FOR ELEMENTARY LABORATORY WORK IN PHYSIOLOGY AND HYGIENE.*

L. MURBACH.
Central High School, Detroit.

INTRODUCTORY GUIDES.

Notes are to be written describing what you observe and think or learn from the observations. They may be somewhat in the form of an essay, but differ from the latter in that you may never write from the imagination. They should be written in such simple and connected form as to be intelligible to any one who has not especially studied the subject. It will be better to write only on the first page of each sheet leaving the back for corrections, if necessary. All notes should be written in ink and just as fast as the information is obtained; they must therefore be written in the laboratory and from specimens, or experiments, and never from borrowed information. If the student wishes to embody information that is contained in these laboratory circulars, or what he has heard from his instructor he should do this with some paraphrase such as "we learn from," or "we were told," etc.; this makes his own observations more valuable.

Drawings of specimens are valuable in securing accuracy and minuteness in observation and also in preserving the results of the work. They should be only outlines of the object, in sharp

*These laboratory directions are offered more for their method than their substance. Of their originality in any particular the reader may judge. They are given here as I am using them this semester with some slight alterations. It is the first time I have had them put in permanent form. The booksellers print them in loose-leaf form, perforated so that they may be fastened in the biology note-book covers. In this way the order of subjects can be changed each term, or all the notes of the class can be taken up and given out as each new subject is begun. The order is that followed the present semester. Sometimes the work is begun with "Foods and Nutrients," and at another with "Respiration." Suggestions and criticisms from interested teachers will be greatly appreciated. It is my intention to enlarge and complete these directions another year.

Any Physiology teacher wishing to see them in advance of the seriatim publication in SCHOOL SCIENCE AND MATHEMATICS may obtain a copy for 25c by addressing Macauley Bros., Booksellers, 172 Woodward Ave., Detroit, Mich.

smooth lines made to scale. The proportion each figure bears to the actual size of the object is to be indicated in the drawing thus, x ½ or x 1. The parts of each object shown should be labeled with the name neatly written. Always write the name of the object, or figure underneath. Keep the object drawn until the drawing has been approved so that any point in doubt may be verified. Under no circumstances may the notes or drawings be examined by another student for points that he cannot, or is unwilling to, work out; the teacher will give legitimate help. Specimens, on the other hand, may be compared with profit as each will vary somewhat from others. Important corrections should not be made without again examining the specimen. Independent, honest work is demanded.

Students should never drink from anything in the laboratory nor taste anything unless directed to do so.

Laboratory work, consisting of observations and experiments, should always precede the study and recitation of a given subject. Thus preceding the study of cells, tissues (bone, etc.), the student should see epithelial cells, or other cells, then some single-celled forms—the amoeba if possible—then striped and plain muscle fibres. In case there are not enough compound microscopes for the class these may be studied with the aid of the lantern or charts. At this point the study of bones (see the circular) may be taken up so as to precede the text For the first lesson in the laboratory the student may become familiar with the method and nature of experimentation from the following explanation and simple experiments.

Experiment Writing.

An experiment is for finding out something that is not naturally apparent or otherwise easily discovered. In nature the conditions are usually such that the results of the activities of a plant or an animal cannot be seen. In an experiment the natural conditions are so changed as to make the result visible. Then we learn (conclude) what takes place under natural conditions. An experiment may be arbitrarily divided into four parts. 1. Usually an experiment is performed with some object in mind. This is the Purpose of the experiment. 2. The operations, instruments, etc., may be called the Conditions of the experiment. Only

essentials should be stated. 3. When an experiment has succeeded the Result will be seen. 4. Understanding the working or attaining the object of the experiment is the Conclusion that we draw from the experiment. It may contain a simpler and a more comprehensive conclusion. The three important steps in an experiment may be kept distinct and remembered more easily if the following facts are understood and kept in mind: The "conditions" of an experiment are what we do in setting up the experiment. The "result" is only what we see after the experiment has worked. It is not what we infer, learn, or think, from the experiment, for that is the "conclusion."

Write up your experiments under the heads, purpose, conditions, result, conclusion. Because of lack of time to try different conditions only typical experiments are given, i. e., those whose conditions will give results that will decide the question. In writing experiments write what was done, seen, and learned; do not write as if giving directions (in the imperative). The student will succeed beter if he does not assume experiments will, or must, come out in a certain way.

SOMETHING ABOUT ACIDS AND ALKALIES.

NOTE.—The nature and names of common things are frequently confused. Popularly the name "acid" is applied to drugs or unknown chemicals. Acids and alkalies are so commonly used that the following experiments are given for learning something about their nature.

EXPERIMENT 1*a*. Some diluted acid, such as vinegar, is poured into a white dish. Litmus paper, first blue, then pink, is dropped into the acid and the resulting color is noted. All true acids give this result. If you cannot write as the conclusion what you have learned in this experiment then leave room for the conclusion until you have applied the experiment by trying: 1b to find out which of a certain number of substances are acids, putting the unknown in place of the acid and testing with litmus paper. Make a table according to the model shown on the board in which to record the unknowns in this and the next (2) experiment. Now write conclusion 1a.—what you learn about use of litmus paper.

EXPERIMENT 2*a*. Into a clean dish some alkali (dilute ammonia) is poured. Litmus paper, first pink, then blue, is dropped into the alkali. What is the result of the experiment?

All true alkalies give the same reaction. Here again if you cannot tell the thing you learn in this experiment leave room for the conclusion until you have made use of the experiment for finding which of the unknown solutions given you are alkalies. Then tabulate your results under 2b. Before leaving this write the conclusion for 2a. Test also as unknowns such common substances as washing soda solution, lime water, baking soda in water, the juice of a sour apple if it can be obtained, lemon juice, etc. Record the results in the above table.

EXPERIMENT 3. To learn to what extent alkalies will affect acids: After placing some diluted acid and litmus paper in a dish dilute alkali (solution of soda) is added, drop by drop, until the color of the litmus paper changes. What is the change in color? What does the color indicate? The alkali combines with the acid until all the acid is neutralized. Try alkali with acid in a similar way. As far as possible suggest practical uses of the knowledge you have thus far gained. Also consult the text-book under acid poisons.

EXPERIMENT 4. A drop of hydrochloric acid is placed on a piece of black goods. When the stain has formed wash with dilute ammonia. Why? Result? Record the experiment in descriptive form, and give practical application in case of acid stains.

SOME OF THE FUNCTIONS OF BONES.

Bones in the skeleton or isolated bones are examined to learn how they are suited for support, and protection of organs of the body. Give your reason for statements made after your examination of several kinds of bones.

EXPERIMENT 1. A piece of long bone has been placed in a 10 per cent. solution of acid for several days. Compare it in stiffness with a bone not treated. What was the result? The acid has removed the mineral matter. What is left? Of what use does the mineral matter seem to be? What desirable quality does the animal (softer) matter give to the bone? What would be the danger if bones were mostly or wholly mineral matter?

EXPERIMENT 1*. For those who have the interest and the time it will be a profitable experiment to remove the animal mat-

*Parts marked by a star * may be done if there is time. Extra credit will be given.

ter from a piece of bone to see what the mineral ash looks like and to get the proportion of mineral and animal matter. A small piece of bone is weighed very carefully in an earthen-ware crucible and then burned over a Bunsen flame. When cool it is again weighed. What is the result? What conclusion?

Study and draw a longitudinal section of a bone showing the structure. The part forming a stiff tube is the shaft of the bone. Learn about the mechanical principle involved. The enlarged ends are for articulation with other bones. Notice how these ends are lightened. Show all these points in the drawing and label each part shown. On the skeleton designate places where muscles were attached to bones, by the ridges to which the muscles were attached. Frequently little holes may be seen where blood vessels passed for the nourishment and growth of the bone.

In the skeleton tell where the following bones according to form are found: 1. Long bones. 2. Short bones (not longer than twice their diameter). 3. Flat bones. Try to explain the function of each kind in a general way. In the same manner locate the following kinds of joints. 1. Ball and socket joints. 2. Hinge joints. 3. Pivot joints (part of elbow).

EXPERIMENT 2. To learn how the bones act as levers in the body experiment with the lever apparatus.[1] Place the bar in position to imitate the arm and forearm. Hook up the spring balance, holding the bar (forearm) straight until the pull supports a 1-pound weight placed at the end of the bar representing the hand. How many pounds pull is indicated on the spring balance. In conclusion apply this to the action of the biceps muscle and the use of the arm. Next arrange the bar to represent the foot putting the spring balance in position of the calf muscle and the weight in position of the ankle. The fulcrum will be at the end where the toe presses on the earth. By comparing the pull on the spring balance caused by a certain weight you can tell how much the calf muscle has to pull every time you raise your weight up on your foot in walking. Solve this problem giving result and conclusion.

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1 This apparatus is described on page 669 of this issue.

RESPIRATION.

Composition of Air—Nature of Components.

Note.—By experiments we can learn many things about breathing. Beginning with the composition of air, we learn that it is a mixture of gases, those best known being oxygen, carbon dioxide, and nitrogen.

Experiment 1. To learn approximately the amount of each, a tube containing.....millimeters (or may be measured in cubic centimeters) of air closed at one end, is inverted in a solution that absorbs oxygen.

Products in Expired Air.

Experiment 5a. Preliminary. To learn the behavior of carbon dioxide with limewater: A centimeter's depth of clear lime water is placed in a test tube and some known carbon dioxide is received into the test tube from the delivery tube of a carbon dioxide generator. The test tube is then closed with the thumb or the hand and shaken. If no result yet appears, add some more carbon dioxide and shake again. How would you describe the appearance of the mixture? If now you are told that only carbon dioxide behaves this way (give this result) with lime water, can you tell what use you can make of this experiment; what you learn to do? If not certain of the answer leave until after the next experiment.

Experiment 5b. To learn if there is any carbon dioxide in expired air (compare note, experiment 1, above): One centimeter's depth clear lime water is poured into test tube and the test tube held under one nostril in such a way that the breath is forced into the tube. This is done several times, each time removing the test tube when a fresh breath is taken so that no air will be drawn out of the tube. The tube is then closed and shaken as in experiment 5a. What is the resulting appearance of the lime water that was previously clear? What is present in expired air? Where did you learn to test for it? Can you now tell what you learned in experiment 5a.

Experiment 6*. To learn whether there is relatively more or less carbon dioxide in the breath than in the air: the air in a tube with one cm. deep lime water is shaken, more air is allowed to enter, the tube shaken again as above, experiment 5b. The amount of turbidity or milkiness (precipitate) in the lime water of the tube with only air, compared with that of the

breath as seen in experiment 5b will enable the student to draw a conclusion.

EXPERIMENT 7*. To learn whether there is any oxygen in the air normally expired: a bent glass tube from the mouth is inserted under a graduated tube (an ordinary small graduate will do) filled with water and inverted in a dish of water. A measured portion of water (simply reading the graduated tube) is replaced by air blown from the lungs through the glass tube. The water in the dish is now made strongly alkaline by adding caustic potash. After half an hour (when the fluid rises no longer, showing that all the carbon dioxide has been absorbed, (Cf. note Ex. 1) the amount of gases left in the tube is again noted. What gases would be left? Now pyrogallic acid is added to the alkaline solution and left until the fluid rises no longer. What indicates whether there is any oxygen in expired air? What is the gas left? Read the amount? From the various readings of gas the proportion of carbon dioxide, of oxygen, and of nitrogen in expired air may be told.

EXPERIMENT 8. To find other products in respired air a clean dry test tube is held so that the breath enters it. The tube is then held to the light so as to see anything that may collect on its sides. Be careful to distinguish what you see from what you learn in this experiment and write it out accordingly.

EXPERIMENT 9. To learn whether there is any difference in the temperature of inspired and expired air. The temperature of the air in the room is read.

NOTE.—While near the thermometer and making the first record, the student must avoid breathing on it or letting the warmth of his body come near enough to make a false record.

After carefully noting the temperature of the air breathed in, the expired air is gently directed on the bulb of the thermometer for some time just as in warming the hands. The temperature is immediately noted. Is the temperature now indicated higher or lower? What does this tell about the air breathed out?

EXPERIMENT 9*. To learn of another product in expired air. At home a clean fruit jar or bottle is filled with breathed air as full as possible by breathing gently into it for a long time. It is then closed air tight and set in a warm place for a day. The next

day the *odor* is examined and the experiment written up in school. What kind of matter can undergo decay in a warm place and give such an odor? What is thus learned to be in the breath?

As a summary, tell four changes air undergoes from inspiration to expiration.

Some Sources of Carbon Dioxide.

In order to be on the lookout for danger from carbon dioxide it is well to know some of its sources.

Experiment 1. A funnel is placed over a gas burner so as to catch as much of the products of burning as possible. A tube conducts the products into a test tube containing 1 centimeter's depth clear lime water. This is thoroughly mixed by shaking. What does the result indicate? (Cf. ex. 5a.)

Experiment 2. A dish of clear lime water is placed under a bell jar with some decaying organic matter and left until the next lesson. When again seen what is the result? Conclusion?

Note.—It may be necessary to stir the dish of lime water to make the result more evident.

From these two experiments and five (5b) the student is to enumerate the sources of carbon dioxide with which we are concerned.

VENTILATION.

Note.—At this point it may be well to learn the principle underlying ventilation to see how the carbon dioxide may be removed.

Experiment 1a. A lighted candle is lowered into a tall narrow glass jar. How does it behave after some time? Can you explain the result? (b) The lighted candle is again lowered and a tin partition is lowered in the jar so as to make two flues. How does this affect the burning candle compared with (a)? If you cannot now explain you will understand better if you will hold a smoking paper or stick over each flue (each side of the partition). What behavior of air underlies all systems of ventilation?

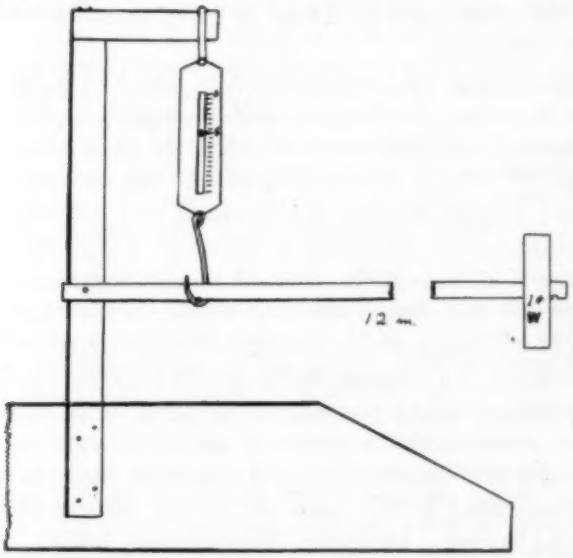
SIMPLE MUSCLE-LEVER APPARATUS.

L. MURBACH.

Central High School, Detroit.

Almost all the elementary books on Physiology and Hygiene give something of the kinds of levers represented by the arm and foot, and even some problems. In many schools this work comes in the earlier part of the high-school course before the pupils have had any Physics and I think they fail to comprehend because of the abstract way the problem is presented. The past summer a way of introducing the subject with a concrete experiment occurred to me and I give it, believing such simple experiments stimulate pupils to further thought and hoping it may prove useful to someone.

The spring balances and the weights are the only thing that



need cost money,—the former cost me thirty cents, the latter ten. My balance weighs 20 pounds in half-pound divisions. One weighing about the same is advertised in the large wholesale catalogues of Chicago firms at five or six cents each.* A more

* Montgomery Ward & Company.

delicate balance, though costing more, is one weighing four or five pounds and graduated in ounces.

For the base an old Barnes' dissecting microscope block was used and to this the upright bar representing the upper arm was fastened with small nails. The projecting piece on top of the upright is secured with two nails and is notched at the free end for the upper ring of the balance. It is well to bore holes somewhat smaller than the nails so as to prevent splitting of the wood. A small lever 12 inches long, representing the fore-arm, is fastened to the upright with a screw or nail in such a position that it will stand upward about 45 degrees when a notch in the under side rests in the hook of the spring balance. The notch for receiving the balance hook should be about one and one-half inches from the joint (fulcrum), the distance the biceps muscle is attached from the elbow joint. For weights any of the kinds for platform scales can be used. Mine is the round flat kind with a slot to the centre, and thus may be hung over the end of the lever rider-fashion.

For illustrating the lever-function of the foot a second upright for supporting the balance will be needed, or the fulcrum end of the fore-arm lever may be supported on a block of suitable height.** Where individual apparatus can be had there will be supports enough for half the balances, and the students can work in pairs. Now the notch in the lower side of the free end of the lever is placed on the hook of the balance so as to be in position of the calf muscle and the weight is placed about two inches from it. This is simply exaggerating the length of the foot for convenience. In this case better results are obained if a much larger weight 10 or 15 pounds can be used, or a balance that weighs in ounces since the power is applied so near the weight.

The pupil after understanding the parts of the apparatus has his attention called to the position of the pointer at the zero mark on the balance. He places the one-pound weight at the end of the lever representing the hand and now reads directly on the balance the number of pounds-pull the biceps muscle exerts in order to lift a one-pound weight in the hand. Any doubt of the correctness of his observation is usually dispelled by asking him to lift the weight first placing his finger under the weight itself, then by placing his finger under the balance hook. And

in answer to the question how much more the muscle pulls than the weight it can lift in the hand he rather readily tells me "eight times as much," and gives as his reason "the distance the weight is off;" yet, if first given the abstract figures (proportion) for getting the muscle-pull for one-pound weight in the hand he does not seem to understand, even if he completes the proportion.

**The open top of a box of suitable size, laid on its side, answers all purposes of supports.

Department of Metrology. Notes.

Metric System in Arithmetics. The unfortunate attitude of some authors of modern arithmetics is illustrated by the following review by Mr. C. S. Wadsworth, of two modern works, Robinson's New Practical Arithmetic, American Book Co., 1892, and Wentworth's Grammar School Arithmetic, Ginn & Co., 1897.

Of the 416 pages of Robinson the first 90 are given to notation, fundamental processes, etc. Then follow 30 pages on vulgar fractions. Pages 121-137 are devoted to decimals, concrete examples of which seem to be entirely omitted. The use of concrete examples in a way calculated to make the subject interesting seems carefully avoided, and the text is dry reading even for an adult. After crossing this 17 page desert, we come to decimal currency, where first we see decimal fractions in practical use. This looks like the cart before the horse. Pages 156-158 give a recondite discussion on "scales," serving as a preface to 73 pages on denominate numbers, etc. Among these last are scattered tables and sufficient information concerning the metric system. The tables omit none of the long and little-used names, and do not attempt to display their simplicity as practically employed. In fact, on page 166 a paragraph dilates on the disadvantages of the system. With a persistent perverseness the author tries to prove metric measure inconvenient here on the ground that the Ar is 1-40 of an acre, and would be absurdly small for a farm in the United States. The author seems never to have read of Hectars, and to be lamentably ignorant of the metric system in practice. A Frenchman might equally well lodge against our system the complaint that square rods are too small for measuring a farm in France.

Wentworth's Grammar School Arithmetic brings in decimals before common fractions, and with concrete examples, but does not, like the old Wentworth & Hill, introduce the metric system as an illustration of decimals. In his preface, Wentworth says the chapter on metric system is put at the end of the book because many grammar school pupils have not time for it, while those who have time can as well learn the system at this stage of their progress as later. This seems like a step backward.

C. S. W.

Problem Department.

IRA M. DE LONG, UNIVERSITY OF COLORADO.

Readers of the magazine are invited to send solutions of the problems in this department and also to propose problems in which they are interested. Solutions and problems will be duly credited to the authors. Address all communications to Ira M. De Long, Boulder, Colo.

ALGEBRA

PROPOSED BY SAUL EPSTEEN, BOULDER, COLO.

4. To complete a certain work, A requires m times as many days as B and C together; B requires n times as many as A and C together; and C requires p times as many as A and B together; compare the times in which each would do it, and prove that

$$\frac{1}{m+1}+\frac{1}{n+1}+\frac{1}{p+1}=1$$

5. PROPOSED BY THE EDITOR.

Find the rational prime factors of x^9-y^9

6. PROPOSED BY MARY C. TRACY, PASSAIC, N. J.

A man is twice as old as his wife was when he was as old as his wife now is; when she is as old as he is now, the sum of their ages will be one hundred years. Find their ages.

GEOMETRY

(Errata.) (1) This should read: In any triangle ABC, if BP, CQ be drawn perpendicular to CA, BA, produced if necessary, then shall $\overline{BC}^2=AB\times BQ+AC\times CP$.

4. PROPOSED BY H. B. LEONARD, BOULDER, COLO.

If perpendiculars AP, BQ, CR be drawn from the angular points of a triangle upon the sides, show that they will bisect the angles of the triangle PQR.

5. PROPOSED BY SAUL EPSTEEN, BOULDER, COLO.

A common tangent is drawn to two circles, which touch externally; if a circle be described on that part of it which lies between the points of contact, as diameter, this circle will pass through the common point of contact of the two circles, and be touched by the line which joins their centers.

6. PROPOSED BY MARY C. TRACY, PASSAIC, N. J.

The circumference of a circle can be divided into five equal parts as follows: Draw two perpendicular diameters AC, DE, meeting at the center B. Bisect AB in F with F as center and FD as radius describe a circle meeting AC in G. Then DG is a chord of one-fifth the circumference. Can this construction be proved geometrically?

TRIGONOMETRY.

PROPOSED BY H. B. LEONARD, BOULDER, COLO.

3. Prove that $\tan^{-1}\frac{1}{3}+2\tan^{-1}\frac{1}{7}=45^\circ$.

MISCELLANEOUS.

1. It is shown in Analytic Geometry that $xx_1+yy_1=r^2$ is the equation of the polar of the point (x_1, y_1) with respect to the circle $x^2+y^2=r^2$. Furnish various proof, giving references for those that have already been published.

NOTES FROM THE UNIVERSITY OF ILLINOIS

The Mathematics Club held its first meeting of the year on September 30 and elected the following officers for the first semester:

President—H. W. Reddick.

Vice President—Miss Jessie J. Bullock.

Secretary and Treasurer—Miss Mabel Kilpatrick.

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Reported by ERNEST B. LYTLE.

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Teachers' Pensions.

SCHOOL SCIENCE AND MATHEMATICS is fully in sympathy with the idea of a Teachers' Pension and Retirement Fund, and gladly gives space to the matter submitted by the New Jersey teachers for discussion.

Whenever a really practical system has been worked out—one that will guarantee to every annuitant a definite sum based upon suitable provisions for eligibility, then should be made by all public school teachers a very general effort for its adoption.

A large number of responses to the questions as asked should be promptly sent.

QUESTIONNAIRE IN RE PUBLIC SCHOOL TEACHERS' RETIREMENT ANNUITY AND PENSION SYSTEMS.

1. Do you believe in the principle of a retirement annuity or pension system for aged and invalided public school teachers?

2. Will you kindly state, briefly, your reasons pro or con?

3. Who, in your opinion, is the greater beneficiary of a retirement annuity system that relieves the schools of teachers of impaired efficiency? Is it the schools, i. e., the people, the state, the community—or the teachers themselves? Your reasons.

4. Should the pension fund be provided by the teachers or the state or the school district? In other words, ought the fund to be a charge upon the teachers, or upon the people at large? Or should it be contributed by both teachers and people?

5. Who should be eligible to membership in such a fund? (This question does not mean "who should be eligible to pension or annuity?" which matter is dealt with under queries 8-15, but what superintendents, supervisors, teachers, teacher-clerks, etc., ought to be privileged to join the fund?)

6. Should membership in the fund be voluntary, or ought it to be compulsory on all teachers, including superintendents, assistant superintendents, supervisors, principals, special teachers and teacher-clerks?

7. What percentage of salary ought members to contribute?

8. How should amount of annuity be regulated? What ought to be its amount? Fixed by what standards? What minimum? What maximum?

9. On what conditions ought annuity to be granted? For disability? For age? For period of teaching service? For age and teaching service combined, etc.?

10. Should a minimum of service combined with mental or physical incapacity (to teach? to earn a sufficient livelihood?) be conditions precedent to retirement on annuity?

11. Ought the rules to permit a teacher to be retired on annuity on his or her demand after a specified term of service? or at a certain age

combined with a certain term of service? If so, what should these ages and terms of service be:

For men?

For women?

12. Should retirement for age be compulsory? If so, at what age, and conditioned on what term of service:

For men?

For women?

13. Or, ought disability to be a condition in all cases?

14. Should retirement on annuity be voluntary or compulsory?

15. If in some cases voluntary, and in others compulsory, name the circumstances that ought to govern either method.

16. Do you favor a retirement system (as in New Jersey) applying to every public school teacher in the state, or a system for teachers in certain cities or cities of a certain class?

17. If you favor the latter system, what provision is to be made for aged and invalided country teachers? How are the country schools to be relieved of instructors who, by reason of age or infirmity, are no longer able to render efficient service?

Kindly answer the foregoing questions by number, and send reply to (Miss) Elizabeth A. Allen, Secretary, 1217 Garden street, Hoboken, N. J. As the period is brief in which our report must be prepared, an early compliance with our request will be greatly appreciated.

MAIN FEATURES OF THE NEW JERSEY PUBLIC SCHOOL TEACHERS' RETIREMENT FUND LAW—ENACTED MARCH 11, 1896; FIRST ANNUITY GRANTED DECEMBER 3, 1897.

Title—"The Board of Trustees of the Teachers' Retirement Fund." ADMINISTRATION, A Board consisting of three members of the State Board of Education, the State Superintendent, and three teachers elected by the State Teachers' Association. The State Treasurer is, ex-officio, Treasurer. MEMBERSHIP is voluntary for any superintendent, supervisor, principal, teacher or teacher-clerk in the public or State schools of New Jersey. DUES are reserved from each salary payment and remitted monthly to the State Treasurer. They are, (1) All New Jersey teachers were given a certain time to join on a salary-deduction of one per cent, (2) At present those who have taught not more than a total of ten years may join for one per cent, (3) Persons joining now who have served more than ten and less than fifteen years must pay two per cent, (4) Those who have taught fifteen years or more must pass a satisfactory medical examination before they may join on the two per cent basis. THE LAW PERMITS THE FUND TO BE AUGMENTED by donation, legacy, gift, bequest, devise or otherwise. ANNUITIES ARE HALF PAY (minimum $250, maximum $600; less one per cent reserved for the Fund), subject to a pro rata reduction if at any time there shall not be sufficient funds on hand to pay in full, and are granted on disability after

not less than twenty years' teaching in New Jersey. Before any annuity may be drawn, the beneficiary must have paid into the Fund an amount equal to at least 20 per cent of one year's average salary for the last five years. Members whose applications for annuity have been granted by the Trustees may make up the balance due in one payment. ANY MEMBER WHO SHALL HONORABLY RESIGN from teaching in New Jersey, except as an annuitant, after contributing to the Fund five years or more, may draw out one-half of the amount paid into the Fund without interest.

One hundred and nine annuities have been granted (19 men and 90 women), to whom have been paid benefits amounting to $93,754.00, while a net surplus of $85,000.00 has been accumulated, which the teachers are trying to raise to $100,000.00 before January 1st.

SANITARY MILK INSPECTION A FARCE.

In the November *Delineator* Mary Hinman Abel has some remarks of vital importance on the necessity of more rigid inspection of milk. To quote in part:

"Whittaker, in his report on the milk supply of New England cities, says that there is 'no especial sanitary inspection of milk and its sources in any New England town or city. Inspection relates to commercial frauds rather than health matters. We find that wherever milk inspection is reported as 'efficiently performed,' as in Boston, the statement refers chiefly to the prevention of 'selling less food than the purchaser supposes he is receiving.' As the geography class says, 'from Maine to California,' it is all the same. To begin with Maine: according to Pearson's report, 'Milk inspectors shall be appointed in towns of more than three thousand inhabitants, and may be appointed in smaller towns.' And yet Portland, its chief city, with fifty thousand inhabitants, reports: 'No milk ordinance and no inspection' to the Government inquiry. In California, to make the regular geographical skip, we find in the law the phrases 'it is the duty,' 'it is prohibited,' 'officers are required,' with many 'shalls' and 'musts' covering apparently all that ought to be covered, and its chief city, San Francisco, reiterates the 'shalls' and 'musts,' even adding the naive order that 'Owners of dairies must report conditions that might render milk impure.' And yet, it is not stated how an ignorant dairyman is to be instructed as to these conditions or what pressure is to be brought to bear to oblige him to make a report as to his own injury. We learn that 'none of the city dairies or dairy farmers sending milk into the city have been inspected;' not strange, certainly, since there is 'no appropriation for the supervision of the milk supply,' and we may be excused from believing that this remarkable order is carried out: 'Swill, garbage or milk diluent must not be carried in delivery wagons.' Detroit, Grand Rapids and Providence have found it necessary to make the same provision as to garbage. For obvious reasons some cities forbid the sale of spring water by the milk peddler."

FIFTH ANNUAL MEETING CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS.

Attention is called to the fifth annual meeting of the *Central Association* of *Science* and *Mathematics Teachers,* to be held

IN THE CENTRAL Y. M. C. A. BUILDING, 153 LA SALLE STREET, CHICAGO, ON NOVEMBER 30 AND DECEMBER 1 AND 2.

This is an association of teachers of science and mathematics in high schools, normal schools, colleges and universities, who are organized for the purpose of keeping abreast with the development of the subjects taught, of advancing the real interests of science and mathematics teaching and those of the individuals who teach. Its membership includes teachers from twelve states. During the present year a number of large mathematical and scientific organizations have become affiliated with this organization with the idea of making this a National Central Association. Though each separate organization maintains its own individuality, all work together for the advancement of common interests, the Central Association being the medium through which co-operation is secured.

It is desired that every person interested in the purposes of this organization should become a member. The membership fee is $2.00 per year and is payable to Mr. Chas. W. D. Parsons, 320 Main Street, Evanston, Ill. Membership entitles one to attend all meetings, to receive all reports published by the Association, to receive the magazine SCHOOL SCIENCE AND MATHEMATICS, which is the official organ of the Association, and to the numerous other benefits that come from being associated with those who are working in scientific and mathematical lines of work.

OTIS W. CALDWELL,
President, State Normal School, Charleston, Ill.
C. M. TURTON,
Secretary, 440 Kenwood Terrace, Chicago.

GENERAL PROGRAM

THURSDAY, NOVEMBER 30

Meeting of the Executive Committee
Great Northern Hotel, at 8:00 P. M.

Applications for membership will be acted upon by the Committee at this meeting, and prospective members should be sure their applications are in before that time.

FRIDAY, DECEMBER 1

9:00 a. m. Exhibits of Apparatus.
10:00 a. m. General Meeting.
Address by Dr. T. C. Chamberlin, Head Professor of Geology, University of Chicago. Subject: "Hypothesis of the Origin of the Earth."

Address by Ernest A. Stirling, U. S. Department of Forestry. Subject: "Relation of Forestry to Public School Instruction."

12:30 p. m. Luncheon.

2:00-5:30 p. m. Section Meetings.

SATURDAY, DECEMBER 2

9:00 a. m. General Meeting
Report of Committees.
General Business.
Election of Officers.

10:00 a. m. Section Meetings.

PROGRAMS OF SECTION MEETINGS

BIOLOGY

FRIDAY, DECEMBER 1, 2 P. M.

Address: "What and How Much can be done in Ecological and Physiological Zoology in Secondary Schools."
OSCAR RIDDLE, Central High School, St. Louis, Mo.

Report of the Committee on "The Course in Biology in Secondary Schools."
WORRALO W. WHITNEY, CHAIRMAN, South Chicago High School, Chicago.

Discussion based on the Committee's Report:

(a), Should Botany and Zoology be Taught in Full Year Courses?
G. H. BRETNALL, Monmouth College.

(b), The relative emphasis to be given to Morphology, Physiology, Ecology and other Phases of Biology.
MISS ELMA CHANDLER, High School, Elgin, Ill.

(c), What, How much, and How field study may be taught?
FRED. L. CHARLES, State Normal School, DeKalb, Ill.

(d), In what order should animal and plant groups be studied?
MISS AMELIA MCMINN, West Division High School, Milwaukee, Wis.

Open Discussion.

SATURDAY, DECEMBER 2, 10:00 A. M.

Election of Officers and General Business.

Joint Meeting with the Physics Section, 10:15 A. M.

The Laboratory Note book problem. Five minute discussions.

"The Technique of Projection and Anæsthesia of Animals with numerous Demonstrations."
A. H. COLE, Lake High School, Chicago.

EXCURSIONS SATURDAY AFTERNOON

(1) Washington Park Conservatory and Field Museum.
(2) Lincoln Park Conservatory and Animal Exhibit.
(3) Uihlein's Orchid Houses.

CHEMISTRY.

FRIDAY, DECEMBER 1, 2:00 P. M.

Recent Advances in Chemical Knowledge.

DR. L. W. JONES, University of Chicago.

Discussion.

"Equipment of a Modern Chemical Laboratory in the Secondary School."

FRED. J. WATSON, Wm. McKinley High School, Chicago.

Discussion.

Reference Books in Chemistry.

F. C. IRWIN, Central High School, Detroit, Mich.

A. B. CROWE, State Normal School, Charleston, Ill.

SATURDAY, DECEMBER 2, 10:00 A. M.

Election of Officers and general business.

Joint Meeting with the Physics Section, 10:15 A. M.

Address: "Investigations of Osmosis."

DR. LOUIS KAHLENBERG, University of Wisconsin.

Address: "New Theories of Matter in Relation to Chemical and Physical Theory."

PROFESSOR CHARLES T. KNIPP, University of Illinois.

EARTH SCIENCE

FRIDAY, DECEMBER 1, 2:00 P. M.

Address: "Commercial Geography for Secondary Schools."

DR. J. PAUL GOODE, University of Chicago.

Address: "The Work of the Hydrographic Office in its Relation to Commerce."

W. J. WILSON, Nautical Expert in charge of the Chicago Branch of the U. S. Hydrographic Office.

Report of Committee on Co-operation in gathering materials for the teaching of Physiography.

CHARLES EMERSON PEET, Chairman, Lewis Institute, Chicago.

Election of Officers.

SATURDAY, DECEMBER 2

EXCURSIONS

(1), To the plant of The Automatic Electric Company, thence through a portion of the tunnels of the Illinois Telephone Company. The party will start immediately after the General Session of the Association on Saturday morning.

(2), To the Fat Stock Show and the Packing Houses at the Union Stock Yards. The party will start immediately after the General Session of the Association on Saturday morning. An admission fee of fifty cents will be charged at the gates. Luncheon may be obtained at the Yards.

(3), To Pullman and the Works of the Pullman Company. This is a joint excursion Saturday afternoon with the Physics Section. For particulars see program of the Physics Section.

PHYSICS

FRIDAY, DECEMBER 1, 2:00 P. M.

Address: "The Value of the Qualitative Experiment in Physics."
L. F. MILLER, University of Wisconsin.
"The Aim of High School Physics Teaching."
E. E. BURNS, Medill High School, Chicago.
Report of Committee on "Reference Books in Physics."
A. H. SAGE, State Normal School, Oshkosh, Wis.
Address: "The Teaching of Physics."
H. N. CHUTE, High School, Ann Arbor, Mich.
"New Forms of Apparatus."
L. B. MCMULLEN, Shortridge High School, Indianapolis, Ind.
Informal Discussion:

(1), Should the attitude of the student be that of discoverer or verifier?
(2), Is consultation of two or more students on a laboratory experiment disorder?
(3), Is it certain that some experiments that require several hours to perform are more valuable to a student than the same time spent in reading?
(4), How many times is it profitable for a student to perform certain experiments for greater accuracy, as, for instance, finding the latent heat of vaporization?
(5), Must the student record every experiment?
(6), Should work with scales and calipers be done in advance for the purpose of learning the use of the instrument, or should the operation be shown for the first time when use requires it?

SATURDAY, DECEMBER 2, 10:00 A. M.

Election of Officers.
Business.
Joint Meeting with the Chemistry Section, 10:15 a. m.
Address: "Investigations of Osmosis."
DR. LOUIS KAHLENBERG, University of Wisconsin.
Address: "New Theories of Matter in Relation to Chemical and Physical Theory."
PROFESSOR CHARLES T. KNIPP, University of Illinois.
Saturday afternoon will be devoted to an excursion to the Pullman Palace Car Works, Pullman, Ill. Train will leave Randolph Street Station of the Illinios Central Railroad at 1:20 p. m.

Those who wish may also visit the Finsen Light Institute of America, Washington Blvd. and Hamlin Ave., or

The Works of the Grand Crossing Tack Co. Everything in the line of brads, nails, tacks and wire is made in this plant. Train will leave Randolph Street Station of the Illinois Central Railroad, at 1:20 P. M.

MATHEMATICS

FRIDAY, DECEMBER 1, 2:00 P. M.

Address: "The Straight Line in Geometry."
J. W. WITHERS, Principal Teachers College, St. Louis.
Discussion.
Reports:
WILLARD S. BASS, Francis W. Parker School, Chicago.
MISS MABEL SYKES, South Chicago High School, Chicago.
Paper: "Interest and Progress in the Teaching of Mathematics."
N. J. LENNES, WENDELL PHILLIPS, High School. Chicago.
Discussion.

SATURDAY, DECEMBER 2, 10:00 A. M.

Election of Officers.
Address: "Aims in Teaching Algebra."
PROFESSOR R. J. ALEY, University of Indiana.
Discussion, led by
MISS JESSIE J. BULLOCK, High School, Champaign, Ill.
Paper: "Some Thoughts on the Teaching of Geometry."
C. A. PETTERSON, Jefferson High School, Chicago.
Discussion, led by
G. C. SHUTTS, State Normal School, Whitewater, Wis.

Book Reviews.

HAND-BOOK AND MANUAL OF PHYSIOGRAPHY.

By Ashley F. Foss.

Neeves Stationery Co., Chicago. 50 Exercises. This book of suggestions is intended to assist those teachers who are confronted with the problem of doing laboratory work with no laboratory and no special material. All of the exercises can be performed in an ordinary recitation room. They are intended to present certain facts of elementary science that are of physiographic interest as well as illustrating some of the more important physiographic conditions. No attempt is made to treat the subjects of weather or topographic maps.

The exercises may be performed by the teacher. Yet practically all of them can be carried out by the pupil.

This manual will be helpful in those schools with but little apparatus.

THE ELEMENTS OF ECONOMICS.

By Charles Jesse Bullock. Silver, Burdett & Co., New York, 1905. 18.5x14 cm. Pages vii and 378.

Believing that some information concerning the facts of modern industry is a pre-requisite to a successful study of the complex theories of industrial forces, the author supplies this information in the body of his text. The first eight chapters, therefore, are devoted to a careful scrutiny of the fundamental phenomena in economic science. The sub-

jects are logically divided, and their sub-topics are so distributed as to give a clear sequence to the arrangement, each theory very clearly set forth in its appropriate chapter. For instance, under the chapter on "The Consumption of Wealth" appear the sub-heads, "Human Needs" and "Statistics of Consumption." Under the next chapter, on "The Production of Wealth," are given a "General Survey" of the topic and an enumeration of the "Factors of Production." This sub-topic then becomes the subject of the following chapter, on "The Organization of Productive Industry," and is there still more fully developed.

"The Theory of Exchange," with its sub-topics explaining "Market Value" and "Normal Value," precedes the chapter on "Money and Credit," which, in turn, explains, as sub-topics, "Credit and Its Instruments" and "The Laws of Money."

In the last half of the book the author gives an account of the present tendencies in economic operation. In his treatment of "Monopolies," "The Control of Railroads," "The Tariff," "The Labor Problem," "Single Tax" and "Socialism," the author proceeds from the basic principles laid down in his first chapters toward a partial solution of the given questions.

Without being entirely devoid of the stamp of the author's own views, the book gives with equal emphasis the opposing views of other writers.

In all cases an effort has been made to concentrate the attention upon modern economic conditions and to formulate the principles upon which these conditions turn. In offering this work as a text-book for high school pupils and for others studying the elements of public economy, the author contributes a most valuable aid to the enlightenment of economic controversy.

Equipped with a thorough knowledge of the elementary forces at work in industrial organization, the boy of the coming generation will be a more useful citizen in dealing judicially with economic problems than is the average adult American of to-day. As the best means of acquiring in its most adequate and concise form this fundamental knowledge, Mr. Bullock's "The Elements of Economics" will find unquestioned favor among secondary schools and business colleges.

THE ELECTROLYTIC DISSOCIATION THEORY.

The Electrolytic Dissociation Theory with Some of its Applications. An Elementary Treatise for the use of Students of Chemistry. By Henry P. Talbot and Arthur A. Blanchard. The Macmillan Co., New York, 1905, v and 84 pp. Price

Here is the book progressive chemistry teachers have been looking for. The electrolytic dissociation theory has proved its usefulness in every field of chemical knowledge, and, while many of its applications are of course out of place in courses of elementary chemistry, yet certain of its bearings at least should be presented in a simple way. This presentation must in secondary schools be largely oral for the reason that elementary texts cannot give the space to a clear treatment of the theory without

crowding out valuable and tried descriptive matter. The teacher then should be conversant with the main points of the theory, and these he will find admirably presented by the authors.

"Evidences of Electrolytic Dissociation Afforded by a Study of the Properties of Solutions," "The Law of Mass Action and the Chemical Behavior of Electrolytes," "Electrolytic Solution Pressure," "Oxidation and Reduction," "The More Common Ions and Their Characteristics," "Experiments"—these are the chapter headings. The careful reading of this book will not only give the teacher a fund of information from which he can draw frequently to the good of his teaching, but will also prove stimulating and helpful.

C. E. LINEBARGER.

Books Received.

Fifty English Classics Briefly Outlined, by Melvin Hix. Hinds, Noble and Eldredge, New York, $1.25, cloth.

Radium and Radio—Active Substances. Their Application Especially to Medicine, by Chas. Baskerville, Ph. D., Professor of Chemistry, College of the City of New York. Williams, Brown and Earle, Philadelphia, 164 pages, $1.25.

Laboratory Experiments in Chemistry, by B. W. Peet, Assistant Professor of Chemistry, Michigan State Normal College. Second edition, revised, 124 pages, 50 cents.

Physics, Mann and Twiss. Scott, Foresman and Co., Chicago, x+453 pages.

Errata for October, 1905.

The article on page 538 should have been credited to E. A. Strong, State Normal College, Ypsilanti, Mich.

First equation on page 558 should read: $5x-20y=10$

Plate 6, page 559, and plate 9, page 561, should be inverted.

The fractions in the article beginning on page 567 should have been alike. Printer's strike prevented the corrections.

For problem 1, Geometry, page 585, see problem department of this number.

PUBLISHERS' NOTICE.

Owing to the printers' strike in Chicago, which is not yet settled, the publishers of "SCHOOL SCIENCE AND MATHEMATICS" are laboring under many difficulties in order to get the Journal into the hands of its readers promptly on the first of the month. We are asking our patrons to bear with us until the difficulty is settled.

SCIENCE AND MATHEMATICAL SOCIETIES.

Under this heading is published each month the name and officers of such societies as furnish this information.

Central Association of Science and Mathematics Teachers.
President, Otis W. Caldwell, State Normal School, Charleston, Ill.
Secretary, Chas. M. Turton, 440 Kenwood Terrace, Chicago, Ill.
Treasurer, E. Marsh Williams, High School, La Grange, Ill.
Annual meeting Friday and Saturday immediately following Thanksgiving.

Chicago Center, C. A. S. and M. T.
President, W. C. Hawthorne, Central Y. M. C. A., Chicago.
Vice-President, P. B. Woodworth, Lewis Institute, Chicago.
Secretary, C. E. Osborne, High School, Oak Park, Ill.

North-Eastern Ohio Center, C. A. S. and M. T.
President, Franklin T. Jones, University School, Cleveland.
Vice-President, Miss Winona A. Hughes, High School, Mansfield, Ohio.
Secretary-Treasurer, Clarence W. Sutton, Central High School, Cleveland.

Association of Ohio Teachers of Mathematics and Science.
President, William McPherson, Ohio State University, Columbus.
Vice-President, Franklin T. Jones, University School, Cleveland.
Secretary, Thomas E. McKinney, Marietta College, Marietta.

Science Section of the Michigan School Masters' Club.
Chairman, H. M. Randall, Ann Arbor.
Vice-Chairman, F. C. Irwin, Central High School, Detroit.
Secretary, DeForrest Ross, Ypsilanti.

New England Association of Chemistry Teachers.
President, Albert S. Perkins, Dorchester High School, Boston, Mass.
Vice-President, Sidney Peterson, Brighton High School, Boston, Mass.
Secretary, Harold Bisbee, Dorchester High School, Boston, Mass.
Treasurer, Edward F. Holden, Charlestown High School, Boston, Mass.

Mathematical Section of the California Teachers' Association.
President, G. A. Miller, Stanford University.
Vice-President, W. H. Baker, State Normal School, San Jose.
Secretary-Treasurer, J. Fred Smith, Campbell High School, Campbell.

Missouri Society of Teachers of Mathematics.
President, H. C. Harvey, Kirksville.
Vice-President, L. M. Defoe, Columbia.
Secretary, L. D. Ames, Columbia.
Executive Council: E. R. Hedrick, Columbia, chairman; B. T. Chase, Kansas City; B. F. Finkel, Springfield; B. F. Johnson, Cape Girardeau; Wm. Schuyler, St. Louis; Miss E. J. Webster, Kansas City.

Mathematical and Physical Section of the Ontario Educational Association.
Hon. President, W. J. Robertson, Collegiate Institute, St. Catherines.
President, C. A. Chant, University of Toronto.
Vice-President, H. S. Robertson, Collegiate Institute, Stratford.
Secretary-Treasurer, R. Wightman, Jarvis St. Collegiate Institute, Toronto.